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TRANSACTIONS

OF THE

Illinois State Academy of Scien

FIFTEENTH ANNUAL MEETIN

Rockford College
Rockford, Illinois

April 27 to 29, 1922

VOLUME XV

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Illinois State Academy of Science

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A. R. Crook, *Librarian.*

State Museum, Springfield, Ill.

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OFFICERS AND COMMITTEES FOR 1922-23.

President, W. S. Bayley, University of Illinois, Urbana.
Vice-President, W. G. Waterman, Northwestern University, Evanston.
Secretary, C. Frank Phipps, State Teachers College, DeKalb.
Treasurer, W. F. Schulz, University of Illinois, Urbana.
Librarian, A. R. Crook, State Museum, Springfield.

The Council.

President, Retiring President, Vice-President, Librarian, Secretary and Treasurer.

Committee on Membership.

H. J. VanCleave, University of Illinois, Urbana, Chairman.
W. H. Packard, Bradley Institute, Peoria.
Fred R. Jelliff, Daily Republican-Register, Galesburg.
Mary M. Steagall, State Normal University, Carbondale.
John R. Ball, Northwestern University, Evanston.

Committee on Ecological Survey.

Henry C. Cowles, University of Chicago, Chicago, Chairman.
Geo. D. Fuller, University of Chicago, Chicago.
W. G. Waterman, Northwestern University, Evanston.
V. E. Shelford, University of Illinois, Urbana.
W. B. McDougall, University of Illinois, Urbana.
R. B. Miller, State Natural History Survey, Urbana.
S. A. Forbes, University of Illinois, Urbana.
A. G. Vestal, State Normal School, Charleston.
H. S. Pepoon, Lake View High School, Chicago.
Clarence Bonnell, Harrisburg Twp. High School, Harrisburg.

Committee on Metric System.

Thos. G. Hull, State Board of Health, Springfield, Chairman.
G. A. Miller, University of Illinois, Urbana.
F. R. Watson, University of Illinois, Urbana.
F. D. Barbour, State Normal University, Normal.
A. C. Longden, Knox College, Galesburg.

Committee on High School Science and Clubs.

J. C. Hessler, Knox College, Galesburg, Chairman.
C. M. Turton, 2059 E. 72nd Street, Chicago.
Frank H. Colyer, State Normal University, Carbondale.
Harriet Strong, Northwestern College, Naperville.
W. S. Bayley, University of Illinois, Urbana.
Clarence Bonnell, Township High School, Harrisburg.
Wm. J. Adams, High School, Galesburg.
Ruth Marshall, Rockford College, Rockford.
Fred D. Townsley, James Millikin University, Decatur.

Committee on Publications.

The President.
The Secretary.
Charles H. Smith, Hyde Park High School, Chicago.

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PAST OFFICERS OF THE ACADEMY.

1908

(First meeting held at Decatur, Feb., 1908, to organize.)

President, T. C. CHAMBERLAIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1909

(Second annual meeting, Feb., 1909, Springfield.)

President, S. A. FORBES, University of Illinois.
Vice-President, JOHN M. COULTER, University of Chicago.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1910

(Third annual meeting, Feb., 1910, Urbana.)

President, JOHN M. COULTER, University of Chicago.
Vice-President, R. O. GRAHAM, Illinois Wesleyan University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1911

(Fourth annual meeting, Feb., 1911, Chicago.)

President, W. A. NOYES, University of Illinois.
Vice-President, J. C. UDDEN, University of Texas.
Secretary, FRANK C. BAKER, Chicago Academy of Science.
Treasurer, J. C. HESSLER, James Millikin University.

1912

(Fifth annual meeting, Feb., 1912, Bloomington.)

President, HENRY CREW, Northwestern University.
Vice-President, A. R. CROOK, State Museum of Natural History.
Secretary, OTIS W. CALDWELL, University of Chicago.
Treasurer, J. C. HESSLER, James Millikin University.

1913

(Sixth annual meeting, Feb., 1913, Peoria.)

President, FRANK W. DEWOLF, State Geological Survey.
Vice-President, H. S. PEPOON, Lake View High School, Chicago.
Secretary, E. N. TRANSEAU, Eastern Illinois State Normal School, Charleston.
Treasurer, J. C. HESSLER, James Millikin University.

1914

(Seventh annual meeting, Feb., 1914, Evanston.)

President, A. R. CROOK, State Museum, Springfield.
Vice-President, U. S. GRANT, Northwestern University, Evanston.
Secretary, EDGAR N. TRANSEAU, Eastern State Normal School, Charleston.
Treasurer, J. C. HESSLER, James Millikin University.

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1915

(Eighth annual meeting, Feb., 1915, Springfield.)

President, U. S. GRANT, Northwestern University, Evanston.
Vice-President, E. W. WASHBURN, University of Illinois, Urbana.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.

1916

(Ninth annual meeting, Feb., 1916, Urbana.)

President, WILLIAM TRELEASE, University of Illinois, Urbana.
Vice-President, H. E. GRIFFITH, Knox College, Galesburg.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.
Librarian, A. R. CROOK, State Museum, Springfield.

1917

(Tenth annual meeting, Feb., 1917, Galesburg.)

President, J. C. HESSLER, James Millikin University, Decatur.
Vice-President, JAMES H. FERRIS, Joliet.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, T. L. HANKINSON, State Normal School, Charleston.
Librarian, A. R. CROOK, State Museum, Springfield.

1918

(Eleventh annual meeting, Feb., 1918, Joliet.)

President, R. D. SALLISBURY, University of Chicago, Chicago.
Vice-President, ISABEL S. SMITH, Illinois College, Jacksonville.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, T. L. HANKINSON, State Normal School, Charleston.
Librarian, A. R. CROOK, State Museum, Springfield.

1919

(Twelfth annual meeting, March, 1919, Jacksonville.)

President, HENRY B. WARD, University of Illinois, Urbana.
Vice-President, GEO. D. FULLER, University of Chicago, Chicago.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, W. G. WATERMAN, Northwestern University, Evanston.
Librarian, A. R. CROOK, State Museum, Springfield.

1920

(Thirteenth annual meeting, Feb., 1920, Danville.)

President, HENRY C. COWLES, University of Chicago, Chicago.
Vice-President, CHAS. T. KNIPP, University of Illinois, Urbana.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, W. G. WATERMAN, Northwestern University, Evanston.
Librarian, A. R. CROOK, State Museum, Springfield.

1921

(Fourteenth annual meeting, April, 1921, Carbondale.)

President, CHAS. T. KNIPP, University of Illinois, Urbana.
Vice-President, MISS RUTH MARSHALL, Rockford College, Rockford.
Secretary, C. FRANK PHIPPS, State Teachers College, DeKalb.
Treasurer, WM. F. SCHULZ, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1922

(Fifteenth annual meeting, April, 1922, Rockford.)

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THE ILLINOIS ACADEMY OF SCIENCE
Office of the Secretary
State Teachers College, DeKalb, Ill.

COUNCIL MEETING

At the call of President Knipp the Council Meeting was held at the Quadrangle Club, the University of Chicago, on June 21, 1921. All the members of the Council were present, viz., President Knipp, Past Pres. Cowles, Vice-Pres. Ruth Marshall, Treas. Schulz, Librarian Crook and Sec'y. Phipps.

The Secretary reported that the Carbondale material for the Transactions was nearly assembled, and soon after July 1 it would be placed in the hands of the printer.

Our membership relations with the A. A. A. S. concerning initiation fees and dues were discussed, and the Secretary was asked to take the matter up with Dr. Livingston of the A. A. A. S., and President Knipp and Treas. Schulz, and after adjusting fees and dues to have new membership cards printed.

By vote the President was empowered to invite the Illinois Division of the Mathematical Association to affiliate with the Academy and to hold their meetings with us hereafter.

By vote the immediate appointment of chairmen for the sectional meetings of the next annual meeting was left with the President.

By vote last year's committee on Ecological Survey holds over for another year.

The President was empowered to appoint a committee of five, to be called the "Committee on High School Science and Clubs." This takes the place of two former committees—Committee on Secondary Science and Committee on H. S. Clubs.

The names of twenty-six (26) local and two (2) national candidates for membership, who had qualified since the Carbondale meeting, were presented by Treas. Schulz and elected.

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The cordial invitation extended by Rockford College, Rockford, for the Academy to hold its next meeting there, was discussed, and by vote the invitation was accepted.

Vice-Pres. Marshall was made chairman, with power to appoint other members, of local committee to make necessary arrangements for the meeting in Rockford.

The date of the Rockford meeting was left for the local committee to decide after a conference with the President and Secretary.

Vice-Pres. Marshall was empowered to extend invitations to nearby institutions, such as the Wisconsin Academy of Science, Arts and Letters and the Science Club of Beloit College, to meet with us in Rockford.

It was informally decided that the next Council meeting should be held in November at Urbana at the time of the High School Conference.

Adjourned,
C. F. PHIPPS, *Secretary.*

COUNCIL MEETING

Nov. 19, 1921

At the call of the President the Council Meeting was held in Urbana at the University Club House. All members of the Council were present.

The President reported that the Illinois Division of the Mathematics Association would meet with the Academy at the annual meeting in the spring to be held at Rockford and would take part in the program. Also the question of their affiliation with the Academy would be voted upon at that time in the Mathematics sectional meeting.

It was voted to hold the Rockford Meeting Thursday afternoon and evening of April 27, and all day Friday, with a field excursion on Saturday to some interesting points along the beautiful Rock River.

It was voted that a program committee of three be appointed for the Rockford meeting, President Knipp to be chairman of the committee. Dr. Cowles and the Secretary were appointed to serve on the committee.

Vice-President Marshall, as chairman of the Rockford local committee, reported that Professor Mullinix and

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Miss Brown were members of her committee, and that a sub-committee had been appointed, and all were working with a view of giving the Academy a hearty welcome and a good time at the Rockford meeting.

The Treasurer gave a preliminary report which showed a balance in the treasury of $713.35.

Since the price of printing our Carbondale Transactions is to be so high this year, the Secretary was instructed to write to the authors of papers and inform them that reprints could not be furnished gratis, but those desiring them could obtain them at cost.

It was voted that it be the policy of the Academy for the present that papers to be printed in the Transactions be limited to twenty printed pages (about 7,000 words).

It was voted that those authors whose Carbondale papers were very lengthy be written to, stating our condition, namely, lack of necessary funds to publish the Transactions, and asking them either to reduce the length of their paper or to pay for all pages in excess of twenty pages.

Voted that we have 1,000 copies of the Transactions printed this year.

By vote it was decided that a sum not to exceed $200.00 be drawn from the treasury to help pay for publishing this year's Transactions, provided the amount appropriated by the State was insufficient.

Treas. Schulz presented a list of candidates, four local and six national, to be voted upon. All were elected to membership.

C. Frank Phipps, *Secretary.*

COUNCIL MEETING

Rockford, April 27, 1922

At the call of President Knipp the Council met at Rockford College, Thursday afternoon, April 27th. The President, Vice-President, Past President, Treasurer and Secretary were present.

The Treasurer submitted a list of thirty names to be voted upon for membership. The Council took favorable action on all of the names.

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The Treasurer also reported that six members had sent in their resignations during the year, and by vote the resignations were accepted. In most cases these members had moved to distant states.

A resolution to be sent to Illinois Congressmen, referring to duty-free importation of scientific apparatus, was presented, and it was voted to approve the resolution. The President was empowered to appoint a committee to study the resolution and to present it at the Academy business meeting.

Several members who were on the Rockford program had written that they would be unable to attend the convention. It was voted that their papers should be published in the Transactions since they had sent to the Secretary either an abstract of the paper or the complete paper.

The vote of the Council in 1921, relative to charging authors for all pages in excess of 20 printed pages published in the Transactions, was renewed for another year. The price of 90c per page, to be charged for each page in excess of 20 printed pages, was decided upon by vote.

The Secretary was instructed to prepare a schedule of prices, based on the last printer's prices, for all pages in excess of 20 printed pages, and for reprints, and to record this schedule in the minutes of the general business meeting.

In view of the fact that the membership of the Academy had increased so materially during the past two years, thereby increasing the duties of the Secretary, and that other details of the Academy affairs had been placed upon the Secretary, it was voted that he be paid a salary of $150 a year in the future for services.

By vote the price of the old volumes of the Transactions printed by the Academy was increased from 75c to $1.50 per volume. This includes volumes I, II, III, VI, VII, VIII, IX and X. The other volumes, IV, V, XI, XII, XIII, and XIV, which were printed by state aid, are still free to members. The Librarian, Dr. A. R. Crook, State Museum, Springfield, is custodian of the above volumes.

C. Frank Phipps, *Secretary.*

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ILLINOIS STATE ACADEMY OF SCIENCE

Fifteenth Annual Meeting of the Academy
Rockford, Illinois, April 27-29, 1922

MINUTES OF BUSINESS MEETING

April 27th.

After calling the meeting to order President Knipp asked for reports of officers. The Treasurer submitted the following report:

Balance on hand May 1, 1921	$ 704.23
Received from Dues, Initiation and Annual	483.15
A. A. A. S. dues collected by the Academy	1,160.25
Received from the sale of Transactions	21.25
	$2,368.88
Paid for stationery, postage, other expenses of officers and committee chairmen	$ 412.48
Paid printing bills	159.83
Paid to A. A. A. S. for dues collected	1,169.25
Amounts refunded	7.00
	$1,739.56
Balance on hand April 27th, 1922	$ 629.32

Several outstanding bills were yet to be paid.

The Treasurer's report was accepted.

Reports of committees called for:

Professor C. F. Hottes sent his report for the Membership Committee by Professor Schulz. This committee sent out 250 invitations during the year to people to join the Academy. The result was that 57 new members were added to our list. Report accepted.

Dr. H. C. Cowles reported for the committee on Ecological Survey. He stated that the committee was made up of some members who were interested in the work, and they had seen to it that certain papers on Ecology were placed on the program of the Rockford meeting. Report accepted.

Professor J. C. Hessler read the report for the committee on High School Science and Clubs. In substance it was as follows:

The effort of the committee has been confined to the attempt to interest high school principals and superintendents in the formation of Science Clubs, and in the

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sending of representatives of the clubs, and members of the science faculties, to the meetings of the Academy of Science. About 120 letters, together with copies of a suggested constitution for such clubs, were sent out to high schools of northern Illinois. The committee suggested for the consideration of the Academy the advisability of taking measures to organize the high schools of Illinois for science by personal means, through leaders who will become acquainted with the schools, teachers, principals and students, as well as the community, and by a personal touch with all maintain an interest in science, even though local teachers may come and go. In some such way high school science clubs can not only be organized and maintained but they can be related in a definite way to the Academy of Science.

The above report was accepted.

The Secretary reported as follows for the Publication committee:

The publication committee has had charge of publishing the Transactions for the 1921 meeting held at Carbondale. Working with the State printers, bids were secured and the job was let to the Joliet Republican Printing Co., of Joliet. On April 25th the first copies were delivered to the Secretary and were mailed out to the Academy members.

The report was accepted.

The Treasurer presented a list of new members, and all were elected to membership. This made a total of 57 new members for the year.

A letter of cordial greetings and best wishes for a successful meeting from the Wisconsin Academy of Science, Arts and Letters, was read by the Secretary.

The President appointed the following committees with instructions to report at the business meeting Friday, the 28th:

Committee on Nominations, H. C. Cowles, chairman, J. C. Hessler and F. C. Baker. Committee on Resolutions, C. H. Smith, chairman, Miss Mary M. Steagall and A. C. Longden. Committee on Auditing, Clarence Bonnell, chairman, H. B. McDougall and R. C. Mullinix. Committee on Resolution relating to duty-free importa-

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tion of apparatus, B. S. Hopkins, chairman, A. J. Dempster and R. C. Hartsough.

Adjourned to meet Friday, April 28th.

Business Meeting, Friday, April 28th.

The meeting was called to order at 12:30 p. m. by President Knipp.

Reports of committees called for:

Dr. Cowles reported for the nominating committee as follows:

Candidates for offices for 1922-'23

President,	W. S. Bayley,	Urbana.
Vice-President,	W. G. Waterman,	Evanston.
Secretary,	C. F. Phipps,	DeKalb.
Treasurer,	W. F. Schulz,	Urbana.
Librarian,	A. R. Crook,	Springfield.

For third member of Publication Committee, Charles H. Smith, Chicago.

For Membership Committee—H. J. VanCleave, Urbana, Chairman, W. H., Packard, Peoria, Fred R. Jelliff, Galesburg, Mary M. Steagall, Carbondale, and John R. Ball, Evanston.

The Secretary was instructed to cast the vote of the Assembly for the above nominations. All were declared elected.

Charles H. Smith reported for the Committee on Resolutions. The following is a condensed report:

Resolutions of thanks were extended to the people of Rockford, to the Board of Education, Rockford College, to the University Club, to the executive committee of the Academy and to Miss Ruth Marshall for all they had done in helping to make the meeting a successful one. Also sincere thanks were extended to the Chamber of Commerce, to President Maddox, Major Hallstrom and Sup't. Lewis for their many courtesies shown to the Academy members.

The committee recommended that the Academy cooperate with, and sanction in every way, the work that is being done by the committee on High School Science and

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Clubs. It recommended that this committee be continued and five more members added to it.

The committee recommended further that the Academy co-operate with other scientific organizations whose purpose it is to promote the use of the metric system of weights and measures, so that the public in general may become familiar with the advantages of this system and proper legislation be enacted; that a committee of five members of the Academy be appointed to be known as the Committee on Metric System, who shall be responsible for putting into effect the above measures.

It was the committee's sad duty to announce the death of Associate Professor William Logan Woodburn, who for twelve years had been in the department of Botany in Northwestern University; the death also of Mr. Francis Daniels, who was to have read a paper before the Academy at this meeting. Mr. Daniels was an attorney, and for many years had been connected with The Pullman Co., Chicago. The death of Professor A. A. Tyler of James Millikin University was also announced.

The following committee on Metric System, as recommended by the Resolutions committee, was appointed by the President—Thos. G. Hull, Springfield, Chairman, G. A. Miller, Urbana, F. R. Watson, Urbana, F. D. Barber, Normal, and A. C. Longden, Galesburg.

The Auditing Committee reported that they had audited the accounts of the Treasurer and found them to be correct. Report accepted.

The committee on Duty-free Importation of Scientific Apparatus reported as follows:

Resolved:—(a) That The Illinois State Academy of Science records its earnest hope that in the tariff legislation now under consideration by the Congress of the United States, provision may be made for duty-free importation of scientific apparatus for the use of educational institutions, a privilege that has contributed in no small degree to the wonderful progress made in science and its applications in the educational institutions of this country during the past few decades.

(b) That this resolution be spread on the minutes of the meeting and that certified copies of it be sent to the

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Senate and House Committees by which the new Tariff Bill is being shaped up, and to each member now representing Illinois in the Senate and House of Representatives.

B. S. Hopkins,
A. J. Dempster,
R. C. Hartsough,
Committee.

On motion of Professor Turton the Committee on High School Science and Clubs was authorized to draw on the treasury for the coming year for an amount not to exceed $50. to help in the work of that committee. Motion passed.

The following schedule of prices for reprints and for extra pages over 20 printed pages for papers in the Transactions was submitted after Council action—Reprints, $1.00 per printed page for 100 copies or less; $1.10 per page for 200 copies; $2.00 per page for 1,000 copies; $5.00 for special cover page on reprints for 200 copies or less; $5.00 for page of table of contents in reprints for 200 copies or less; 90c per page for all pages in excess of 20 printed pages in the Transactions.

Meeting adjourned.

The papers presented at the general and section meetings were very much enjoyed by the members, by Rockford College students and faculty and by citizens of the city. As nearly as could be calculated there were between 150 and 200 Academy members present. The members were guests of the Rockford University Club for dinner Thursday evening. The president of the Club, Senator H. S. Hicks, gave a cordial welcome to all in a pleasing address. The evening program was preceded by addresses of welcome by President Maddox of Rockford College, Mayor Hallstrom of the city, and Sup't. Lewis of the public schools. President Knipp made a fitting response for the Academy.

Friday morning the members attended the College Chapel exercises in a body, and Dr. Cowles gave a much

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appreciated talk on the work of the Academy. The banquet in the evening was largely attended, and this feature of the convention was, as usual, an enjoyable one.

About 35 members started Friday evening for the field trip to Apple River Canyon. Under the guidance of Dr. H. S. Pepoon, Dr. H. C. Cowles and Mr. M. F. Kleeberger the trip was made interesting to all. The party returned to Chicago Sunday afternoon.

Between 30 and 40 members went on the short trip Saturday down the Rock River Valley. The Rockford Chamber of Commerce furnished autos for the party, and Dr. M. M. Leighton, Urbana, and Mr. P. B. Riis, Sup't. of Parks, Rockford, acted as guides. At the close of the trip, on motion of Professor Bayley, a unanimous vote of appreciation was given to Dr. Leighton for his care of the party under his charge, and for his patience in answering the numerous questions asked him concerning the geology of the region traversed.

Concerning the convention as a whole, many of the members voiced the opinion that it was one of the best the Academy had ever held.

C. Frank Phipps,
Secretary.

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GENERAL PAPERS

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"PRODUCTION OF SOUND BY THE APPLICATION OF HEAT"

(Experimental)

CHAS. T. KNIPP, UNIVERSITY OF ILLINOIS

(Abstract of Retiring President's Address)

That a tone of considerable intensity may be produced by heat is not new. Lord Rayleigh in his treatise on "Sound" describes several experiments dating back as far as 1875, in one of which a sonorous sound was obtained by placing a small flame within and near one end of a glass tube. This experiment, which is referred to in all text books on physics, is known as Rijke's experiment and was possibly the best example of the production of sound by the application of heat until recently. Another example is the glass blower's bulb in which a freshly blown small glass bulb while still hot emits a clear tone as the stem is removed from the lips. Both of these instances are fully discussed by Rayleigh, yet the true explanation of the cause of the tone, especially in the latter case, is not clearly understood.

Several years ago the writer chanced to be working with Pyrex glass (the new refractory glass from which baking dishes are made) and while blowing a tube to serve as a mercury vapor trap, it, quite by accident, began to emit a clear and apparently pure tone. The emission of the note was unlooked for and came as a complete surprise. The phenomenon was as unusual as it was novel and it at once suggested a fruitful field for research. It proved to be intensely interesting and many striking and unusual phenomena were recorded.

While the "singing tube", as it came to be known, seems to be primarily of scientific and educational value, yet there is also a practical aspect. The following experiments and observations have been made:

1. The tube may have a variety of forms; however, the underlying principle of sound production is the same in all.

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2. The tube under normal conditions emits a pure tone which is the fundamental, as shown by photographs of the wave form.

3. The vibrating air column is accurately one quarter of the wave-length of the tone emitted.

4. The pitch may be varied over a wide range by extending or shortening the length of the vibrating air column.

5. The air within the tube is set in violent stationary vibration.

6. Because of the purity of the tones emitted two singing tubes sounded simultaneously are well adapted for the production and study of beats.

7. This vibration results in there being a considerable back pressure at the inner end of the vibrating column.

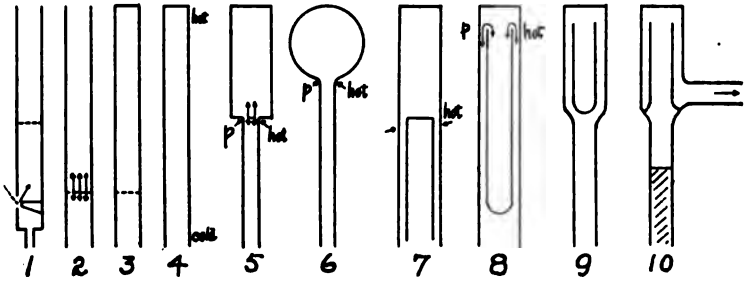
8. If the tube is lengthened indefinitely the fundamental dies out and overtones appear instead. At times the two may be heard simultaneously.

9. The intensity of the tone emitted may be increased many fold by attaching a horn.

10. Each tube has a particular point at which the heat must be applied in order that maximum intensity of sound may be attained.

11. The pitch is practically unaffected by changes in the heating temperature, while the intensity is very much increased with increase of heat.

12. The tube may be used as a standard of sound to the extent that the energy (heat) supplied can be kept



Figures 1-10
A Physical Explanation of the Action of the New Singing Tube.
By Chas. T. Knipp and Jacob Kunz, November, 1921.

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constant. The best means of supplying heat is by electric current.

13. The dimensions of the various diameters of the tube are critical; however, as stated above, the various lengths are not.

14. The open end of the tube forms practically a point source of sound,—little or no sound coming from the other portions of the tube.

15. The tube when the open end is sealed is, on heating, set in violent vibration, yet it emits no sound. This vibration may be converted into sound by placing closed end on a proper resonating body.

16. The temperature difference between the cold portion and hot tip when the tune is sounding is about 400°C or 750°F.

17. The tube may be made to sing by cooling the body of tube to the temperature of liquid air, i. e. to —180°C or about—300°F, and leaving the tip (that is ordinarily heated) at room temperatures.

18. The temperature difference necessary when liquid air is used is about 200°C.

19. By extrapolation this means a temperature difference of only 80°C when the body of the tube is cooled to absolute zero.

20. Recent experiments show that the energy necessary to maintain the sound is from 2 to 3% of that supplied to the tube.

Experiments illustrating most of the above items were performed.

The following physical explanation of the action of the new singing tube is offered:*

In the organ pipe, energy is supplied by a stream of air which encourages the vibrations in a one-sided way, so that the vibrating column receives an impulse each time when the air moves upward towards the node in the middle of the pipe, Fig. 1, and receives no impulse in the opposite motion. It looks as if a pendulum were kept in oscillation by receiving at one end of its path an impulse always in the same direction. If we would apply

* In collaboration with Dr. Jakob Kunz, University of Illinois.

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the momentum of the air jet at the center of the tube, vibrations of the column would be discouraged.

We can communicate momentum to a vertical open air column by heating it. If we heat the air in a tube, 2, by a wire net placed in the lower half of the tube, we will obtain a uniform current of air upwards. If the air is vibrating then as it is moving inward its vibration is increased by the momentum of the upward stream of air, but not increased by moving downward. When we place the hot wire net in the middle of the tube it will tend to increase the pressure of the gas when it is a minimum, i. e., it will discourage oscillations. The same will happen when we place the hot net above the middle. In order to encourage oscillations we have to add momentum in a position and at a moment such that the pressure in the node increases more than it would do because of the oscillations alone. If we put the hot wire net at the lower end of the tube, i. e., in a loop, the effect will be very small, or zero. The transfer of heat will depend upon the temperature of the air in contact with the wire net, being greatest when the temperature is lowest. But the temperature in the loop at the lower end does not vary; therefore, the transfer of heat in this position of the gauze does not give rise to oscillations. It tends only to raise the temperature of the gas uniformly. *Heat must therefore be applied between a loop and a node.*

If we cover the upper end of the tube, Fig. 3, with the hot net in the most favorable position, the sound ceases, and if we heat by means of a Bunsen burner the outside at the top, as in 4, we get no sound. This was considered by Rayleigh** as possible. But if we change the cross section of the tube as in 5, and heat at p, then the tube will emit a sound. The pressure in the upper half of the tube will increase, partly because the air is heated, partly because of the condensations of the air in the node on the top. The air will expand, and now the expansion in the narrow neck is aided by the air being heated by the wall. Here the oscillations are encouraged because each time when the air is expanding by the oscillation the expansion is increased by the heat. In each cycle the vibrating

** Theory of Sound. Vol. II. p. 231.

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particle receives one push in the right direction. It is this one-sidedness of the action which encourages the oscillations. Moreover, as the heat here has the tendency to increase the pressure near the node, the oscillations will start very readly. A slight modification of this experment is the glass blower's bulb, 6, which emits a sound when heated round about the neck, p. Instead of making the lower part of the tube narrower, as in 5, we might proceed as in 7, where the annular area takes the place of the narrow tube, in 6. A modification of this tube is the tube of Fig. 8, which will sound when heated at p, and which is much more sensitive. It is evident from the explanation that this tube will not sing when the lower end of the inner tube is open, because the one-sidedness of the action is destroyed. Slight modifications of 8 are the tubes represented by 9 and 10. If we place a hot wire net inside the tubes 5, 6, 7, 8, 9, 10, where the hot flame was out-side, the tubes will produce a sound. In all cases, in the organ pipe, in Rijke's experiment (tube 2) and in the tubes 5-10; the oscillations of a column of air are maintained by a one-sided addition of momentum at the right moment and in the right place.

These experiments belong to a large variety of phenomena in which a direct motion is transformed into a periodic motion, or, electrically speaking, where direct current is transformed into an alternating current.

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RESEARCH IN APPLIED ACOUSTICS AT THE WALLACE CLEMENT SABINE LABORATORY

PAUL E. SABINE, GENEVA

The problem of the behavior of sound within an enclosed space is as old as the art of public speaking. Vitruvius in his classic work on Architecture gives an admirable analysis of the conditions within an auditorium necessary for good hearing. Since that time it has been the subject of many opinions, enlightened and otherwise, as well as one of considerable popular interest. It is not too much to say, however, that it is one of the latest of physical problems to which the modern scientific method of exact quantitative experimentation has been applied. As a result the subject is even yet shrouded in mystery in the minds of many, and numerous false notions are still current.

The Wallace Clement Sabine Laboratory of Acoustics was built for the researches of the late Professor Sabine by his friend Col. George Fabyan. It is located at Riverbank, one mile from Geneva and thirty-seven miles west of Chicago. The work that is now being carried on there is a continuation of the Research in Architectural Acoustics begun in 1895, and carried on by Professor Sabine with remarkable skill and vigor up to the time of his death three years ago. A brief review of this earlier work constitutes a necessary introduction to an outline of the present activities of the new Laboratory.

These investigations had their inception in the necessity for correcting the acoustic properties of the Lecture Room of the then new Fogg Art Museum at Harvard University. The lines and proportions of this room corresponded very closely to those of Sanders Theatre, the large assembly room of the University, and were not in any marked degree different from those often found in theatre design. Although the volume of the new room was only one-fourth as great as that of the older room, yet it was found that its acoustic properties were such originally as to render it almost impossible of use as an

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audience room. The general problem then confronted was that of determining all the factors that enter into the acoustic merits or demerits of a room. Its complete solution should be quantitative, not qualitative merely, so that its application might be used to anticipate results, not merely to follow and explain them. Consideration of the examples just cited shows that shape alone is not a determinative factor. Further, size is not alone decisive, for we should expect conditions in the smaller room to be better than in the larger, whereas the reverse proved to be the case. The sequel showed that, in this particular case, the difference lay in the relative rates at which sound was absorbed by the walls, ceilings, and furnishings of the two rooms. Sound, once produced in a closed space, is a form of energy, filling the space, until converted into some other form of energy. Mere reflection from hard, rigid surfaces will diminish its intensity but very slightly. Only as the vibrations of the air particles constituting the sound energy do work against frictional and viscous forces is that energy absorbed and dissipated. It was in this particular that the two rooms differed most widely. In the first, a great deal of wood sheathing was used in the interior finish. The seats for some fifteen hundred persons were furnished with cushions, while aisles and open floor spaces were heavily carpeted. In the latter, walls and ceilings were of hard plaster, the seats were uncushioned and the floors uncarpeted. As a result, the rate of absorption in the second room was so small that a word spoken in an ordinary tone of voice persisted as audible sound for five or six seconds. Thus successive syllables, even when spoken most deliberately, were merged into the residual sound from many preceding syllables, and the result was a confusion of sound, amply loud, but one in which the separate elements of speech could be distinguished only by a distinct effort.

The point thus arrived at was simply a qualitative explanation of why two rooms, similar in shape, may possess acoustical properties that are decidedly different by virtue of the difference in their sound absorbing powers. To be of practical value, it was necessary to know the relation between the time of reverberation and the various

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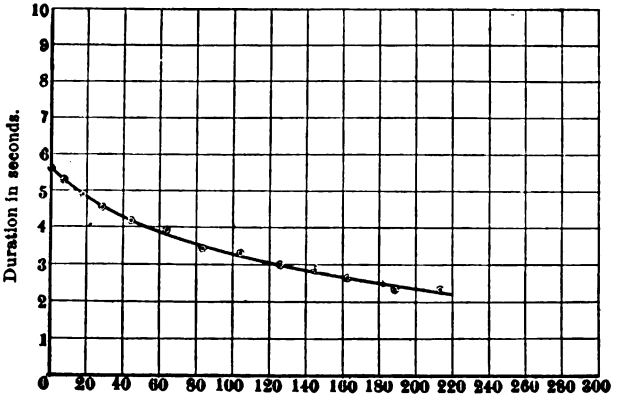
factors upon which it depends. Clearly this time will decrease as the area of the absorbing material is increased. Making a virtue of the defects of the room to be studied and corrected, Professor Sabine determined the general relation between the time of reverberation and the absorbing area. Cushions from Sanders Theater were brought into the room in varying amounts, and the time of reverberation from a selected organ pipe arranged to speak with uniform power was determined in each case by means of a chronograph. Figure 1 shows the reduction of this time from 5.5 seconds in the empty room to 2.14 seconds after 220 meters of the cushions were introduced. An analytical expression for this curve



Curve showing the relation of the duration of the residual sound to the added absorbing material.

Figure 1.

appears immediately when the data are plotted in a somewhat different way as shown in Figure 2. Here the ordinates are the reciprocals of the times. The upper scale represented the actual length of cushions introduced. The points so determined lie very close to a straight line so that we may write

$$\frac{1}{t} = [Lr + Lc]\ 1/k$$

Clearly Lr is the length of cushions that has an absorbing power equal to that of the empty room. If now, the origin of co-ordinates be shifted to the left by an amount

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Lr and we use as our unit of absorbing power, the absorbing power of 1 meter of cushion, setting *a* equal to the total absorbing power of room and cushions, we may write

$$\frac{1}{t} = a\,1/k \quad \text{or}$$

$$at = k, \text{ a constant quantity.}$$

This experiment yielded the important fact that in a given room, the time of reverberation of sound of a given

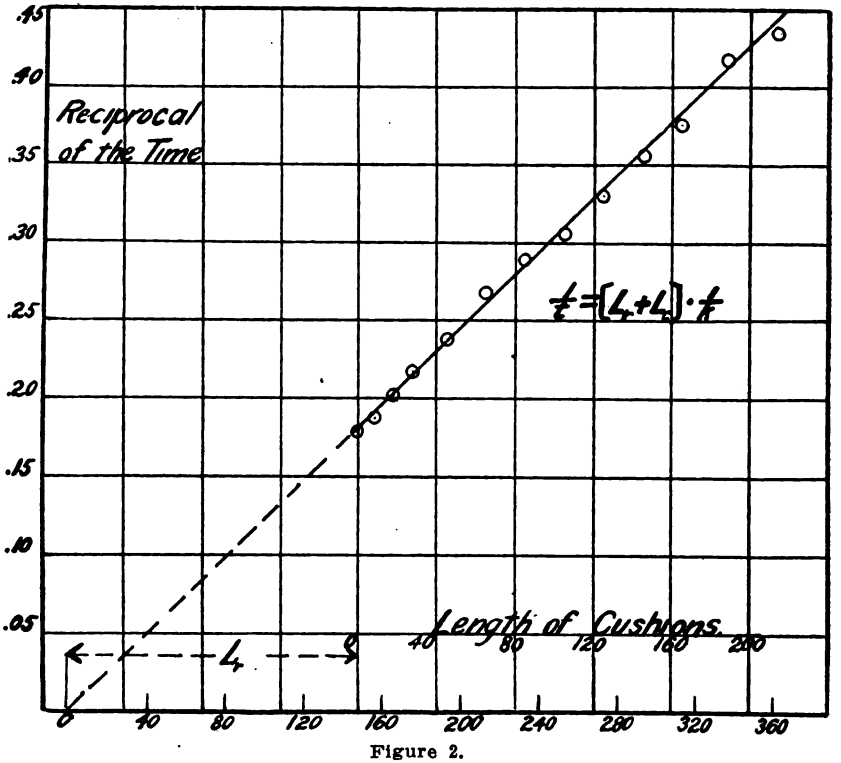

Figure 2.

initial intensity is inversely proportional to the total absorbing power of the room and its contents. Further, it suggested a means by which the absorbing efficiencies of different materials may be compared quantitatively with that of some standard material. Thus by substituting for the cushions, a known area of heavy rugs, let us say,

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and noting the duration of audible sound under these conditions, the ratio of the efficiencies of rugs to cushions may be determined. Naturally, the next step in the investigation was the determination of the absorbing power of the cushions in terms of some more universally accessible and more permanent unit. Viewed from the standpoint of reverberation, it is immaterial whether the sound energy is dissipated as heat, as is the case in true absorption, or escapes from the room through an opening. Experiments in rooms with a large number of windows showed that open windows are also effective in reducing the time of reverberation. The relative efficiencies of cushions and open windows were determined in the manner indicated above. Assuming that the latter acts as a perfect absorber*, the absorption co-efficients of a large number of materials that are used in the interiors of auditoriums were measured as outlined above, and have been published from time to time in Architectural and Scientific Journals.

Extending the experiments to a large number of rooms of different volumes, it was shown that the constant product of absorbing power and time of reverberation is directly proportional to the volume of the room. Using sources of different acoustical powers, the times of reverberation were found to be proportional to the logarithms of the initial intensities.

In the foregoing, we have gone somewhat in detail into these first experiments merely to illustrate the method by which quantitative sound measurements have been made with apparatus no more complicated than a stop watch and the unaided ear. Pursuing this method through a course of the most careful investigations covering a period of more than twenty years, Professor Sabine secured data, and developed a complete theory of auditorium acoustics, which makes the remedy of faulty conditions entirely possible, and, what is practically more

* Recent experiments show that this assumption is true only in special cases. Theoretical considerations indicate that the fraction of the sound that passes through an opening is not in general unity, and that a portion of the incident sound energy is reflected. The relation between the reflected and the transmitted portions depends upon the dimensions and the shape of the opening as well as upon the wave length of the sound. It is to be said that later work is not based upon this assumption.

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useful, enables the architect to provide in advance of construction for acoustic conditions, with the same assurance as he provides for lighting and ventilation. Finally, the progress of the investigation developed an extremely useful means of making acoustical measurements, which may be called the Sound Chamber method. Having established the relation existing between the time of reverberation, the absorbing power and the volume of the room, and the acoustical power of the source, it is possible to compute the intensity in terms of minimum audible intensity at any time after the source has ceased. The only other physical factor upon which this time depends, the acuity of hearing of the observer, enters into the problem in such a way that the results are independent of its absolute value. Hence, although this threshold intensity may vary widely with the pitch of the sound, and be markedly different for different individuals, yet measurements made by different observers prove to be quite consistent.

The Laboratory at Geneva was built primarily for the purpose of applying this method of acoustical measurements to the study of the transmission of sound through building constructions. Figure 3 shows the arrangement for measuring the transmission of sound by standard types of partitions as well as by any other construction or material. The Sound Chamber is an empty room 27 x 19 x 19 feet, with walls of brick, eighteen inches in thickness. As shown, there is no structural connection between this room and the rest of the building. The arrangements for excluding sound from without is such that observations requiring complete silence in the room can be made while others are at work in the building. Openings into three smaller rooms called Test Chambers are made in the walls of the Sound Chamber. In these openings, which are of different sizes, the largest being 6 x 8 feet, the partitions to be studied are built. Heavy steel doors can be closed over these openings, so that it is possible to restore the room to standard conditions whenever control experiments are necessary.

The source of sound is a complete organ of seventy-two pipes, voiced so as to give as nearly pure tones as

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possible. The wind pressure for the organ is supplied by an organ blower driven by an electric motor placed just outside the Sound Chamber The acoustic insulation between the blower and the organ is so good, that although there is a direct air passage between the two, the noise

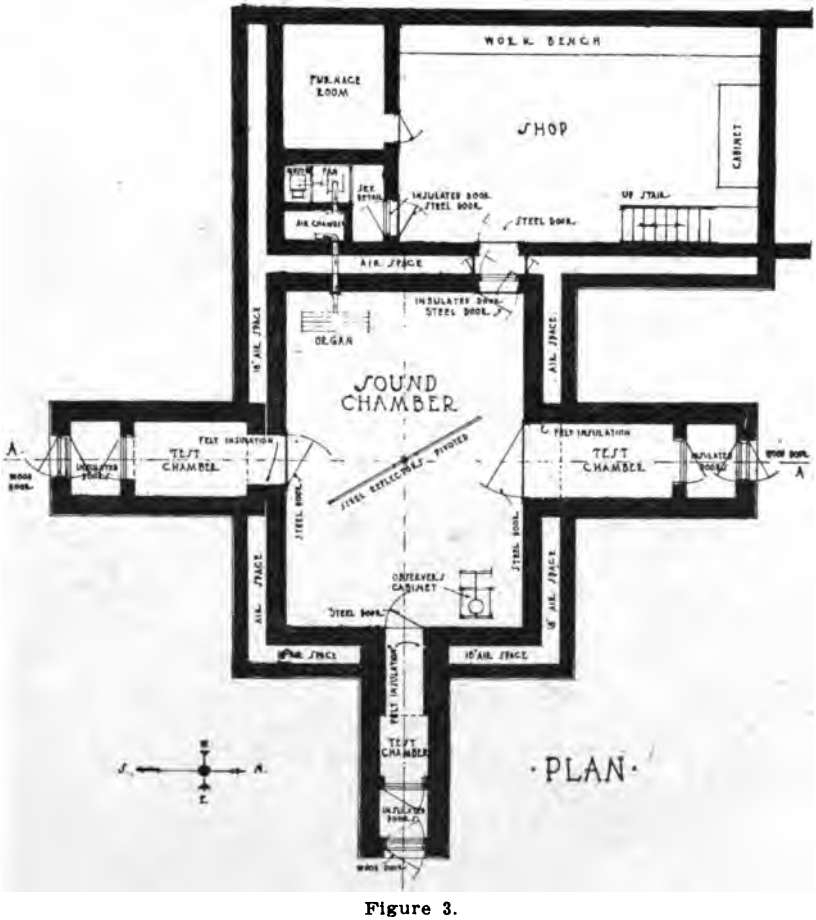

Figure 3.

from the blower is entirely inaudible in the Sound Chamber. The organ is operated from four different keyboards, one in each of the Test Rooms and one in the Sound Chamber. By means of a specially designed stop-watch chronometer, the duration of audible sound in the larger room, and as heard in the smaller rooms through

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the partitions being studied, can be measured with a high degree of accuracy.

From these measurements, the relative intensities of the sound upon opposite sides of the partition being studied are easily determined. Seated in the Sound Chamber, the observer causes any desired pipe to speak. A single electric contact stops the sound and starts the chronometer. This contact is maintained as long as the sound is audible and is broken the instant the sound ceases to be heard, the time being automatically recorded. This operation is repeated in the test chamber, with the partition to be studied intervening. Now it has been shown that although at any one point the sound fluctuates through maximum and minimum values as it dies away, yet on the average taken throughout the room, the intensity decreases according to a logarithmic law, that is, the average intensities at successive equal intervals bear a constant ratio to each other. Hence the logarithms of the ratio of the intensities on the two sides of the partition is proportional to the difference of the times during which the sound remains audible in the Sound Chamber and in the Test Chamber. The factor of proportionality involves only the absorbing power of the Sound Chamber, its dimensions and the velocity of sound. The first of these is known from an initial calibration, made with sources of sound of known acoustical outputs. Illustrative of the general method, the computations are given for a wall made of two inch solid gypsum block plastered on both sides. (Figure 4.)

Calculation of Relative Intensities of Sound, pitch 512 d. v., on opposite Sides of a Wall made of 2″ solid Gypsum Block, plastered on both sides with Gypsum Plaster.

I_1 = Intensity inside
I_2 = Intensity outside
t_1 = time of residual sound inside = 13.48 seconds
t_2 = time of residual sound outside = 8.44 seconds
a = absorbing power of room = 4.40

$$\log_{10} \frac{I_1}{I_2} = .126a\,(t_1 - t_2) = .126 \times 4.40 \times 5.04 = 2.80$$

$$\frac{I_1}{I_2} = 631$$

Fig. 4.

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In this way, the study of a large number of materials as well as of various structural units has been made. It is important to bear in mind the different processes by which the vibrations set up by any source of sound in one room may result in aerial vibrations in an adjoining room. If the vibrating source is in solid connection with the floor or wall, these vibrations may be conducted directly along timbers or beams to the floors or walls of adjacent rooms. Probably the greater proportion of the sound from a piano, cello, or any stringed instrument resting on the floor, as well as the hum of motors or machinery, is transmitted through buildings in this way. Thus far, no attempt has been made to deal with this aspect of the problem. In the case of sound of the voice or from an organ pipe, the alternating pressures in the aerial sound wave in one room produce vibrations of walls or partitions, which in turn communicate their motion to the air of the adjoining room. In the case of porous materials, such as felts or fabrics, the motion of the air may be communicated directly through the pores of the material, with little or no motion of the partition itself. The problems so far studied all come under the last two heads.

The case of solid impervious partitions is illustrated by doors and windows. Here the partition acts as a heavy plate, having its own natural frequencies of vibration. Its response to tones having these frequencies will theoretically, at least, be much greater than to other tones. Hence we should expect the sound transmitted to vary widely with the pitch. The experiments amply justify this conclusion, so that a complete study of the transmission of sound by a single partition involves measurements for a large number of tones covering the entire musical range. The results here presented are for six or seven tones, at octave intervals, covering the entire musical range from 64 to 4096 vibrations per second.

Figure 5 shows the effect of both stiffness and mass upon the transmission of sound by glass windows. The ordinates of the curves give the logarithms of the reduction of intensity of tones given on the horizontal scale.

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The lowest curve shows the reduction produced by a window with panes 3/16 of an inch thick, composed of two thin sheets of glass with an intervening sheet of celluloid. Curve 2 is for a similar window with panes of solid plate glass of the same thickness. The effect of the greater stiffness of the solid glass pane in producing a greater reduction in the intensity of the transmitted sound is shown. Curve 3 is for an identical window using plate glass ¼ of an inch thick. Translating the logarithmic reductions into numerical ratios, the curves for the heaviest window show a reduction in the ratio of 100 to 1 at middle C and a reduction of about 500 to 1 for tones in

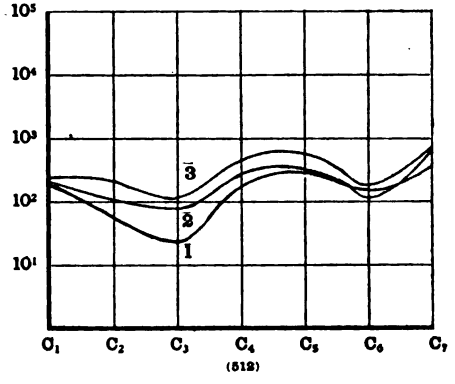

Figure 5.
Curve 1. Reduction produced by triplex glass. Curve 2. By 3/16″ plate. Curve 3. By ¼″ plate.

the second octave above middle C. In Figure 6, is shown the relative transmissions of sound by a single and a double pane window. The lower curve gives the reduction produced by a window of lighter glass than those shown in Figure 5. Curve 2 is for a double glass window, the panes being set in putty upon opposite sides of the sash, with an intervening air space of 1¾ inches. The third curve is for the same window, the panes being set in felt rather than in putty. As is shown, the merit of the double glazed over the single glazed construction is slight for the lower tones, but the former produces a somewhat higher reduction for the upper tones. Similarly, the effect of the felt in reducing the transmitted sound is negligible for the lower tones, but does produce a

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marked effect in improving the sound insulating properties for higher tones. Similar tests conducted upon a number of window units of various types justify the

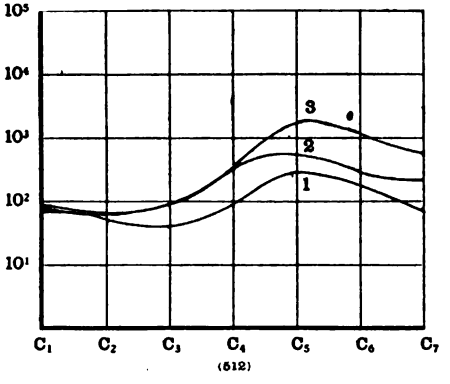

Figure 6.
Curve 1. Reduction produced by single glazed window 3/16″ plate. Curve 2. By double glazed window, with panes set in putty. Curve 3. By double glazed window, panes set in felt.

statement that the sound-insulating properties of such constructions depend upon the mass and stiffness of the entire unit rather than upon the properties of the materials used.

Figure 7 presents the reduction of sound intensity produced by doors of various types. Curve 1 is for a light

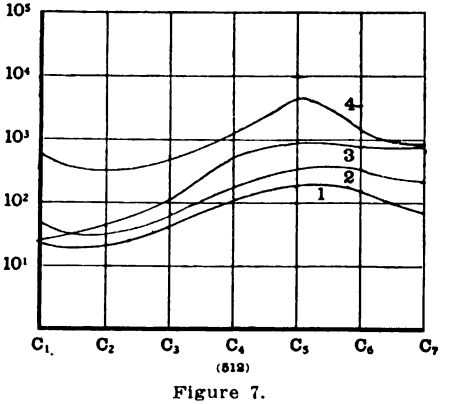

Figure 7.
Curve 1. Reduction produced by door of ¼″ steel. Curve 2. By ¼″ plate glass with cross bracing. Curve 3. By ¼″ plate without cross bracing. Curve 4. By 3/16″ small leaded panes. Curve 5. By ⅛″ panes 10″ x 19″.

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four panel door of birch veneer. Curve 2 is for a solid oak door, 1¾ inches thick. Curve 3 shows the reduction produced by a double walled "ice box" door, made of heavy pine, the intervening space being filled with heat insulating material. Interestingly enough, it was found that a solid steel door, ¼ of an inch in thickness, was much more effective in reducing the amount of the transmitted sound than were any of the other door constructions tested. Curve 4 indicates that, in general, only about 1/1000 of the sound was transmitted by this door. The net results of these investigations point to the conclusion that the highest degree of sound insulation is in the use of materials having the greatest mass and stiffness, rather than in those in which the natural damping is greatest.

It has been generally supposed that soft flexible materials possess great virtues in preventing the passage of sound. This opinion, no doubt, arises from their known value as insulators for heat, as well as to their property of being highly absorbent of sound. Our experiences in the use of such materials in securing the necessary sound insulation in the laboratory led to serious question as to the validity of this belief. Accordingly a study of a number of materials of this general character has been made. Due to its wide spread use as a sound absorbent for the reduction of reverberation, uncovered hair felt was the first material tested. In Figure 8, the logarithmic reductions of intensity of transmitted sound produced by different thicknesses of this material are shown. The point of most practical significance is the relatively small reduction of intensity of the transmitted sound as compared with material such as glass and steel. For all but the highest tones, four inches of this material is less effective than one-fourth of an inch of plate glass. It will be further noted that the sound insulating efficiency rises rapidly with rising pitch. If the logarithmic reduction be plotted against the thickness of the material as in Figure 9, the relation is seen to be linear, that is, each succeeding layer reduces the intensity of the transmitted sound by a constant ratio. This leads to the conclusion that the reduction of intensity by such a material is a

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pure absorption process, and makes it possible to express the insulating efficiency in terms of the thickness and two experimentally determinable coefficients. The extension of the study to a large number of materials of the same character leads to the general conclusion that their insulating efficiencies follow the order of their densities.

Another, somewhat different application of the Sound Chamber method has been an experimental study of the

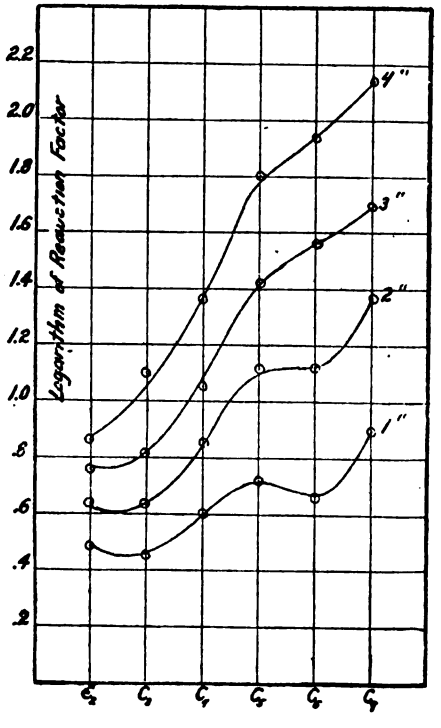

Figure 8.
Reduction of Intensity of Sound transmitted by Hair Felt of varying thickness, plotted as a function of the pitch.

sound amplifications produced by various hearing devices. The actual effectiveness of artificial aids to defective hearing has never been the subject of any more precise determination than the opinion of their users. Accordingly, an investigation was conducted to determine the efficiencies of a number of the more commonly used devices for the aid of the deaf. The eleven different in-

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struments tested may be classified as "Sound Collectors", "Sound traps", speaking tubes, and telephones. Under the first group may be included all the modifications of the simple conical horn. The observations were made by a deaf observer, Mrs. M. H. Liddell, of Lafayette, Ind., whose skillful aid it is a pleasure to acknowledge. They consisted in timing the duration of audible sound, with the instrument held to the ear, and without. From the difference of these times, the amplification of sound is computed as in the case of reduction by parti-

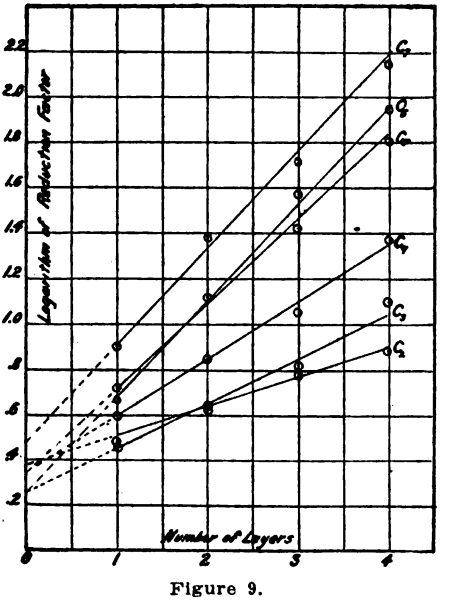

Figure 9.
Reduction of Intensity of Sound of different pitches transmitted by Hair Felt, plotted as a function of the thickness.

tions. The results showed that the order of amplifications produced followed that of the relative sizes of the instruments. The largest one tried produced a magnification of some twenty fold. It is of interest to note that simply holding the hand to the ear was as effective an aid as any but the largest of the ear trumpets. The instruments which I have denoted as sound traps are modifications of the open horn, obviously designed to secure magnification of sound intensity by reflection and focusing of the sound by curved surfaces. That such effects

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are not produced was evidenced by the fact that devices of this character were no more effective than the open horn of the same dimensions. To reflect sound as a mirror reflects light, the dimensions of the reflecting surface must be large as compared with the wave length of the sound. When it is recalled that the wave lengths of tones in the middle register are of the order of several feet, it is apparent that any amplifying device based upon such a principle must of necessity be prohibitively large as a portable instrument. Hence there is no virtue in such instruments when small, other than that of their simple action as resonators.

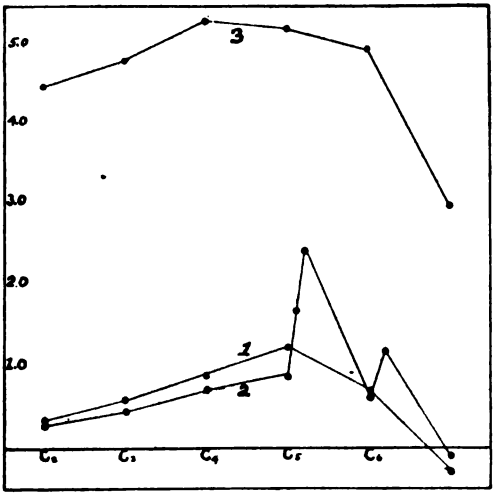

Figure 10.
Logarithmic amplifications of Sound intensities produced by artificial aids to hearing. See Text.

Telephonic devices proved to be much more efficient as sound amplifiers than the simpler ear trumpets. In instruments of this type, however, the maximum amplifications are limited to a small range of tones in the neighborhood of the natural frequencies of the transmitter and receiver diaphragms. The logarithmic amplifications produced by the largest of the ear trumpets [curve 1] and by one of the better known telephonic devices [curve 2] are shown in Figure 10. The upper curve shows the amplification necessary to enable the deaf observer to hear sounds as faint as those that can be heard by normal

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ears. Expressed in terms of physical intensity, the amplification required to produce normal sensitivity for this observer is of the order of 100,000 fold. The best of the ear trumpets produced a magnification of some twenty fold, while the telephone at the frequency for which it was most efficient magnified the intensity some two hundred fold.

Study of the ear, regarded simply as a piece of physical apparatus, has been a field of investigation sadly neglected by physicists. What is known of the performance of the ear in a quantitative way is lamentably small. Otologists readily admit that the physical methods they are forced to employ for want of better are deplorably inadequate, as compared with similar methods employed in the diagnosis of defects of vision. A program of investigation in this field has been begun. The first problem attacked has been that of the determination in absolute units of the minimun sound intensity that will produce the sensation of sound. The results of previous investigations on this question have shown enormous differences. Thus Wien, working in Germany, obtained results indicating a sensitivity of normal ears for tones in the middle and upper registers 10,000 times as great as that determined by Lord Rayleigh. In our Laboratory, Mr. F. W. Kranz has spent almost two years upon this problem. Using a number of methods, results have been obtained, discordant at first, but now showing satisfactory agreement, as sources of error have been eliminated one after another. The energies to be measured are extremely small, and the experimental difficulties are great. Perhaps the most striking of the results is the wide variation of apparently normal hearing. Of the twenty normal ears examined, the least sensitive required for the perception of the tone 512 vibrations, 100 times that required by the most sensitive. At a pitch two octaves above this, the maximum variation of sensitivity was by a factor of 1,000. In general, the range of tones for which the ear is most sensitive is the third octave above middle C, where the sensitivity is about 10,000 times as great as for the octave below this tone. In the region of maximum sensitivity, Mr. Kranz' measurements indicate

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that amplitudes of vibration of the same order as atomic dimensions, namely 10^{-8} cms., produce the sensation of sound. The extension of the method to other problems of audition promises to yield much valuable information upon a subject in which such knowledge is badly needed.

These are some of the problems that have been attacked and partially solved during the three years of the Laboratory's existence. Beginnings have been made upon others, and there is still a large group for the study of which the Laboratory affords most excellent facilities. One of the most fundamental of these is the development of standard sources of sound of easily measurable acoustical output. An equally fundamental desideratum for acoustical measurements is a means of measuring sound intensity as energy, simply, independently of its pitch. All of our sound measuring devices give readings that are functions of both pitch and intensity, so that both of these factors must be taken into account in acoustical measurements as now made. The status of our present investigational methods is that which existed in the measurement of radiation before the development of the bolometer and the sensitive thermo-couple. Rapid advance in the quantitative study of acoustical problems awaits the development of corresponding means for sound measurement. The measurement of noise, which is sound without definite pitch characteristics, is at present impossible.

One of the outstanding lessons of the war was the discovery of the military and naval possibilities of acoustical methods. Equally impressive was the discovery of the entire inadequacy of our quantitative knowledge of this branch of Physics. The control and reduction of sound becomes one of vital importance in view of the multiplication of sources of noise in this mechanical age and the increasing congestion of living and working conditions of modern life. Hence research in Acoustics offers a pleasant prospect of contributions of practical value to scientific knowledge, and a laboratory devoted to this purpose should fill a useful place in the scheme of things scientific.

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THE ATOM OF THE CHEMIST.

W. H. RODEBUSH, UNIVERSITY OF ILLINOIS.

The chemist has believed in the existence of the atom for more than one hundred years. The fact that the different elements combine to form compounds in certain definite proportions by weight can be most easily explained by assuming each element to be made up of discrete particles, all of the same mass in a given element but of different masses for different elements. But while this explanation of the laws of chemical combination was the only satisfactory one that could be offered, nevertheless, until a few years ago, not a single direct proof of the existence of atoms had been obtained. As a matter of fact, about twenty years ago a school of chemists arose, headed by Ostwald, who doubted the existence of atoms. They said the atomic theory was an attempt to explain nature by a crude mechanical analogy, and that matter was not the coarse grained sort of affair that these literal minded people made it out to be. They said that the people who believed in atoms did so because they had a psychological intuition which they got from observing dust particles. One can divide a dust particle into finer and finer particles, but the imagination balks at continuing this process of division indefinitely. So these literal minded people said that one must ultimately arrive at a particle of such fineness that it could not be further divided and hence is the indivisible atom. Likewise, said the antagonists of the atomic theory, these people think of a liquid like water not as a fluid but as a discontinuous medium made up of hard, solid molecules which were freer to slide over one another, for the reason that the human mind grasps the idea of particles of unchanging size and shape much more readily than it does that of fluid matter. And so a gas, instead of being a continuous medium able to expand indefinitely, must be made up of hard elastic particles flying about in space.

On the other hand, these literal minded chemists, and they comprised a great majority, went ahead serenely

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building up a system of chemical combination based upon the assumption of indivisible atoms—a system which has proved extremely fruitful in bringing the facts of chemistry, especially organic chemistry, to light and which constitutes one of the most remarkable achievements of human intelligence. Within the last few years, by a series of brilliant experiments, the existence of the atom has been established beyond a doubt. For most of the direct evidence of the existence of the atom we are indebted to the physicist. But the physicist was not content with demonstrating the existence of the atom. He has gone ahead and shown that the atom is made up in turn of electrons and positive nuclei and is of such complexity as to defy our comprehension. His work has proved that both schools of chemists were wrong. Atoms exist, but they are not the hard, indivisible particles that the chemist thought them to be. They are perhaps nothing but systems of electrical particles. These particles themselves are nothing but centers of electrical force. There is nothing left for the man whose imagination works through his tactual sense to rub between his fingers and say, "This is matter." The man who was happy with hard, indivisible atoms is no more comfortable with this complicated atom that the physicist has forced upon him than he would have been in the old days without any atoms at all.

The chemist is interested primarily in the ability of atoms to combine with atoms of other elements to form chemical compounds. The numerical measure of the ability of an atom to combine with other atoms has been called its valence, and the force which binds one atom to another, as to the nature of which we have been until recently very much in the dark, has been designated as the valence bond. By ascribing to hydrogen one valence bond, oxygen two and carbon four, the organic chemist has built up a most extraordinary system of chemical valence which not only applies almost perfectly to several hundred thousand compounds, but which may almost be said to predict the existence and the properties of this vast number of compounds as well as innumerable

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other compounds which yet await syntheses in the laboratory.

When we come to inorganic chemistry, the situation is different. In the first place, the valence of many of the elements is not a simple, definite number, but is a variable quantity, some of the elements having as many as seven different numerical valences. In the second place, the valence bond is a different sort of a thing than the one we met in organic chemistry. If we electrolyze sodium chloride which has been brought into a liquid condition by solution or melting, the sodium travels in the direction of the positive current, and the chlorine in the opposite direction, thus demonstrating that the sodium atoms are positively charged and the chlorine atoms negatively so. It has been recognized since the time of Faraday that the attraction of the positively charged sodium atom for the negatively charged chlorine atom would account fully for the valence bond in sodium chloride. It remained for the brilliant researches of Bragg and Bragg to show just how and why this was so. Physical experiments show that a sodium chloride crystal is made up of alternate positive and negative charges arranged in a so-called simple cubic arrangement, each positive charge surrounded by six negative charges, and each negative charge surrounded by six positives. These charges are not to be confused with the electron or elementary positive charge, however. For with the positive charge is associated a mass equal to that of the sodium atom and with the negative charge a mass equal to that of the chlorine atom. Evidently, then, we have the charged atoms acting as indivisible units and bound to each other by electrostatic forces alone. In valence bonds of this nature, therefore, number has lost its significance, for apparently one sodium atom may attract the six chlorine atoms which surround it with as much force as it would attract a single chlorine atom in a sodium chloride molecule in the gaseous state. Evidently, therefore, if we were to try to write sodium as we do carbon, oxygen and hydrogen in organic chemistry, with a certain number of dashes to represent its valence, we

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should be at a loss whether to put one dash to represent the sodium atom, or six. With the understanding, however, which the physicist has given us of the structure of sodium chloride, the uncertainty of the valence number causes us no difficulty; rather, the new viewpoint of the matter makes easily understandable the many interesting properties of that large class of substances of which sodium is a conspicuous example, known as electrolytes.

On the other hand, in the case of the organic compounds, where the number system of valence works so satisfactorily, we have no physical evidence as to the structure or arrangement of the atoms in the molecules except that the atoms do not seem to be charged as they are in the case of sodium chloride. We must still rely upon the intuition of the chemist rather than the direct experiment of the physicist for an explanation of the force which we call a valence bond. Many chemists still prefer to regard valence as an abstract numerical property of the atom and content themselves with taking it as it exists without worrying about why it is so. On the other hand, with the conception of the atom as a positive nucleus whose charge is its atomic number surrounded by electrons, a physical chemist believes that valence is not simply a number, but that it can be explained in all cases as due to electrostatic forces between the positive nucleus of one atom, and the outer electrons of the same and other atoms. The theory of G. N. Lewis has met with most remarkable success in explaining the combination of atoms in the molecules. This theory is based upon the conception of the atom which the physicist has given us, and I shall try to sketch for you its essential features.

Let us consider the elements from lithium to neon inclusive, which form the first row of eight in the periodic table. Lithium has an atomic number of three, glucinum, four, boron five, and so on, to neon with an atomic number of ten, the elements being placed according to their atomic number. The atomic number is the number of positive charges on the nucleus, and we represent the nucleus of the atom by writing the atomic number with

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a plus charge after it. The neutral atom then must have as many electrons around the nucleus as it has positive charges on the nucleus. It should be observed that except in the cases of substances like sodium chloride where the atoms are alternately positively and negatively charged, the atoms must be on the average neutral. In our representation of the electrons, we have apparently arbitrarily placed two of the electrons close to the nucleus and the remaining electrons are arranged at some distance away from the nucleus. The following consideration, however, shows the justification for doing this. When lithium combines with fluorine to form lithium-fluoride, we get a salt which resembles sodium chloride. The lithium atom becomes positively charged and the fluorine atom negatively charged. This can be brought about only by an electron passing from the lithium atom to the fluorine atom. The lithium atom, however, never loses more than one electron. This is a fact which has been recognized for a long time. Even before the electron was discovered, it was thoroughly understood that the lithium atom could acquire only one positive charge while the glucinum atom combines with two fluorine atoms and acquires two positive charges. That is to say, the glucinum atom may lose two electrons. Since it has four electrons, however, apparently there are two electrons in it just as in the lithium atom which may not be lost. We find the same considerations to apply throughout the rest of this row of elements, and we assume that these electrons are closer to the nucleus than those electrons which take part in a chemical reaction Those electrons which take part in a chemical reaction we, somewhat arbitrarily perhaps, assume to be at a greater distance from the nucleus and designate them as valence electrons. A valence electron, then, is an electron in the periphery of the atom. Lithium has one, glucinum two, boron three, and so on up to neon which has eight. Lithium combines with one fluorine atom, beryllium with two fluorine atoms, boron with three and carbon with four. Lithium fluoride and glucinum fluoride are salt-like in their character, that is, they resemble sodium chloride, and the valence bonds

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which hold them together may be ascribed to the electrostatic forces between the atoms when an electron passes from one atom to another leaving the one atom positively charged and causing the other atom to be negatively charged. Compounds of this type are called polar compounds because the molecule consists of a positive and a negative atom or atoms resembling a magnet with a north and a south pole. The reason that the electron passes so readily from the lithium atom to the fluorine atom appears to be because the positive charge upon the nucleus of the fluorine atom is so much greater than that upon the lithium atom. The recipe for making a polar compound, that is, one of salt-like character, then, is to take two atoms with a considerable difference in the positive charge upon their nuclei. This rule is subject to a modification which will be obvious a little farther on. When that modification is introduced, it is found to be verified absolutely by the facts of chemistry. When we consider boron trifluoride, we find that the difference in positive charges upon the nuclei of the two atoms in question is not so great. Therefore, the tendency for an electron to leave the boron atom and go to the fluorine atom will be very much less. As a matter of fact, boron trifluoride does not appear to be a polar substance, that is, of salt-like character, and when we consider carbon tetrafluoride, where the fluorine has only three positive charges more than the carbon, we have a compound which has no resemblance whatsoever to a salt. There is no reason to believe that the electron has left the carbon atom and gone to the fluorine atom, and we are forced to the conclusion that the valence bonds here must be quite different in character from those in lithium fluoride. G. N. Lewis has proposed the theory that the valence bond in a compound of this non-polar type consists of two electrons occupying a position somewhere intermediate between the two atoms. We do not have time to go into the detailed considerations which led Lewis to the idea that a non-polar bond consisted of two electrons. We can only try out the arrangement of a number of compounds to see how it will work out and, of course, that is in the last analysis the only consideration of importance in regard

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to any theory. It may be noted at once, however, that if two electrons are to be placed between atoms for each valence bond, it will in general lead to an even number of electrons in any molecule. Remarkably enough, all but a very few of the hundreds of thousands of chemical compounds do contain an even number of electrons. It may be noticed that if we take the old valence theory of organic chemistry where carbon has four valence bonds and hydrogen one, and assume that these valence bonds link, not with each other, but from atom to atom, then the electron in the Lewis theory of valence simply replaces the valence bond in the old system. The application of this theory of valence to organic chemistry in general, then, becomes very simple.

Since carbon combines with four fluorine atoms, we might expect nitrogen to combine with five and oxygen with six. But no such compounds occur. The reason appears to be fairly obvious. The forces of repulsion between the nitrogen and fluorine nuclei are so great that the atoms refuse to remain in combination with each other. When we come to the neon atom, we find a peculiar state of affairs; neon does not combine with any other atom. We might explain its refusal to combine with nitrogen or oxygen as due to the repulsion of the positive nuclei, but there appears to be no reason why it should not take an electron away from a weak atom like lithium. The conclusion which we are forced to is this: Neon has eight electrons in its outer or valence shell. There must be something about the geometry of the arrangement of eight electrons about an atom which makes it peculiarly satisfactory to the forces between the electrons. Eight electrons may be comfortably arranged in the outer surface of the atom but no more electrons may be introduced into this arrangement. Sodium, with an atomic number of eleven, resembles lithium in its properties and can acquire only one positive charge. That is to say, it has only one valence electron. We must conclude then that in the sodium atom the eight electrons are in a condition similar to the two electrons in the lithium atom. We then represent the sodium atom as

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having eleven positive charges upon its nucleus, two electrons close to the nucleus, eight more outside of these two, and the one valence electron still outside these eight forming the beginning of a new shell of outer or valence electrons. The second row in the periodic table thus becomes a repetition of the first row, the number of valence electrons increasing with the atomic number until we reach the rare gas argon, the only difference being that the second row has an inner shell of eight electrons The chemical properties of these elements bear out this conclusion absolutely. If time permitted, we could go on through the periodic table of elements, showing how the properties of these elements may be explained by assuming that the electrons are arranged in series of shells, one about the other, the outer shell always composed of the valence electrons.

Since this group of eight seems to be a peculiarly stable arrangement for the electrons about an atom, we should expect that those atoms which have less than eight electrons in their outer shells would try to acquire eight electrons when they enter into a chemical compound. This proves to be the case. It does not apply, of course, to those atoms which are relatively weak, that is, those atoms which have a small positive charge upon the nucleus, because we have seen that when they enter into chemical combination they lose their valence electrons entirely. But, for the atoms beginning with carbon, which do not lose their valence electrons to another atom in a chemical combination, we find in a vast majority of cases they combine with other atoms in such a way that they complete their shell of valence electrons up to the number eight. An inspection of such typical compounds as carbon tetrafluoride, methane, ammonia, water and hydrogen fluoride, will show that this is the case. The hydrogen atom, it may be remarked here, with only one positive charge upon its nucleus and only one electron of any kind, appears to be completely satisfied with two electrons instead of eight. But this is what we might expect since we have been led to the conclusion that all atoms have two electrons arranged very close to the nucleus. Hydrogen and helium with atomic numbers of one

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and two, then, are to be placed in a series by themselves at the beginning of the periodic table—the hydrogen atom anxious to acquire two electrons by chemical combination and the helium atom, having two electrons already, refusing to combine chemically with anything. Helium gas is absolutely unreactive chemically.

The chemical properties of any atom, then, are to be explained by the number of valence electrons it possesses and the pull upon these valence electrons exerted by the positive nucleus. If the pull exerted by the nucleus is very strong, as in the case of chlorine, which not only retains its valence electron with great force but strives to acquire additional ones, we say that the element is electronegative. If the force upon the valence electrons is weak, as in the case of sodium, we say that the element is electropositive, meaning, of course, only slightly electronegative since all atoms must be regarded as exerting some pull on their valence electrons and hence being electronegative to some degree. Now the concept of atomic number would lead us to expect that the atoms would increase continuously in electronegativety from hydrogen, with an atomic number of one, up to uranium with an atomic number of ninety-two, since the force upon the valence electron should be proportional to the atomic number by the ordinary laws of electrostatics. As a matter of fact, the electronegativety is a periodic function of the atomic number. The atoms may be arranged in the well known periodic table in periods of two, eight, eight, eighteen, eighteen, thirty-two and thirty-two. The electronegativety rises to a maximum at the end of each period and drops almost to zero at the beginning of the next period, and the greatest electronegativety in the whole periodic system is reached in the element fluorine[1] with an atomic number of nine. It was to explain this periodicity of the elements that Lewis and Kossel introduced the concept of shells, concentric about the atomic nucleus. Each period ends in an inert gas where presumably a shell of electrons is completely

[1] Actually, neon may be supposed to be more electronegative than fluorine, but since it does not combine with any other element it is not ordinarily so considered.

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filled. With the first element in the next period, then, there must be the beginning of a new shell. Thus sodium has one valence electron forming the beginning of the second shell of eight around the first shells of two and eight, each in the interior of the atom. The first question, then, that arises, is why does the positive nucleus exert so slight a retaining force upon this valence electron? The answer seems to be this: The valence electron is at a considerably greater distance from the nucleus than the inner shells. The electrons in the inner shells tend to neutralize the attractive force of the positive nucleus for this valence electron. The whole sodium atom, then, exclusive of this valence electron, may be regarded as having a net positive charge of one only, which acts as though it were centered in the nucleus. The force exerted, then, upon the valence electron will be relatively weak. Futhermore, the valence electron of sodium is farther from the nucleus than the valence electron in the lithium atom. Thus, according to Coulombs law, the force exerted upon an electron by a positive charge is inversely proportional to the square of the distance between them. The electron in the sodium atom is then at a greater distance from the nucleus than in the lithium atom and should be retained with less force. This is the case. Sodium is less electronegative than lithium. This explanation may be applied consistently to the properties of the elements throughout the periodic table. The electronegativety rises to a maximum at the end of each period, but each maximum is actually less than the preceding as we go from one period to another, because of the increasing distances of the electrons from the positive nucleus.

This application of the laws of electrostatics to explain the properties of the atom must be recognized as being only qualitative. The unsolved problem is why this arrangement of electrons in shells around a positive nucleus is stable at all. Undoubtedly there is something in the geometry of arrangement of electrons which determines how many electrons may be crowded into any shell. When we study the properties of the more complex

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atoms, we find evidence that the outer shells are no longer perfectly definite arrangements in number, but that they are more or less variable in their makeup. Electrons may apparently shift from one shell to another. But the geometry of the atom can hardly explain why the electrons do not fall into the powerful positive nucleus. That they do not is a fact. Why they do not is a problem for the physicist rather than the chemist.

The importance of symmetry in the stability of electron arrangement should be emphasized. We have already mentioned Lewis' observation that so comparatively few of the many thousands of compounds contain a total number of electrons (measured by the sum of their atomic numbers) which is odd. Those which do are relatively unstable and almost without exception highly colored. Apparently when the number of electrons is odd, instead of each electron's having a definite position, one or more electrons are able to oscillate between two or more positions, thus absorbing light of some wave length in the visible spectrum and causing the phenomena of color. It has been noted that the complex atoms have a variable structure in their electron shells. These atoms are all colored.

To repeat, the most important question is, why the shells of electrons do not collapse into the positive nucleus.

The physicist has offered an explanation, and a natural enough one. He says that the electrons are rotating around the positive nucleus in orbits just as the planets rotate around the sun, and that they do not fall into the nucleus for the same reason that the planets do not fall into the sun. The chemist has a very grave objection to this dynamic atom of the physicist. The chemist has reason to believe that the atoms are combined in molecules of extraordinary complexity and rigidity of structure. These molecules retain their structure unchanged throughout the ordinary processes of fusion, evaporation and chemical reaction. The chemist believes that the atoms are held together in these molecules by electrons which occupy definite positions between the different

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atoms. It is almost incomprehensible how these electrons can be rotating around these atoms in orbits and at the same time bind the atoms together in fixed and definite arrangements of molecular structure. Many chemists therefore have preferred to believe in the static atom, that is, one in which the electrons are arranged in stationary shells, preferring to leave the stability of the shells unexplained rather than adopt an explanation which appears to destroy the chemical property of the atom we call valence.

The physicist is concerned mainly with the explanation of such phenomena as radiation, and this dynamic theory of the atom explains radiation very well, provided the physicist discards a considerable portion of the classical theory of electrodynamics. He has the same justification in doing this that the chemist has in discarding Coulombs law as being operative at small distances between electrons and positive nuclei. That is, each explanation seems to fit the facts. The facts which the physicist and the chemist are trying to explain are thus of a different sort. To the chemist an atom which is radiating light is in a pathological condition. It appears to be impossible for an atom to be brought into a condition in which it radiates, without destroying the molecule of which that atom is a part. The dynamical theory of the atom, then, explains the properties of the atom in one condition; the static theory explains the properties of the atom when it is in another condition. The two theories may not be contradictory—they may simply apply to two different states of affairs. The problem to be answered, then, in the immediate future is not whether these two theories may be reconciled, but rather, whether they are dealing with the same phenomena.

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STELLAR EVOLUTION

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It is becoming more generally and more clearly recognized that the source of the sun's heat does not lie in the gravitational contraction of the sun. It is true that if the sun had contracted from infinity to its present size the heat thus generated would be sufficient to supply the sun's present rate of radiation for about twenty millions of years. Not only is there no evidence that the sun was ever larger than it is at present, but even though we grant that it was larger, twenty millions of years is altogether inadequate to satisfy the geological requirements as to the age of the earth. The methods of determining the age of the earth from the thickness of the sedimentary rocks and from the amount of salt in the oceans agree in giving a minimum age of at least three hundred millions of years, while the radioactive method determines the age of certain of the Archean rocks to be as high as sixteen hundred millions of years. It seems unlikely that even this figure represents the full age of the earth. Estimates recently made by Chamberlin and by Lord Rayleigh range from three to ten billions of years. Evidently the contraction hypothesis furnishes less than one per cent of the amount of heat that is necessary for the life history of the earth.

Turning from a study of the earth to a consideration of the dynamics of stellar systems it is seen that the difficulty is multiplied many fold. There are over eighty groups of stars which are known as globular star clusters. They contain many thousands of stars in what seems like a very minute region of the sky. Actually this size is very great, for the stars of which they are composed are doubtless, on the whole, comparable to our sun. Each star moves to and fro in the cluster under the gravitational attraction of all of the other stars of the cluster. This process of oscillating back and forth has gone on for so long a time that the clusters have arrived at a steady state of motion in which the motions have become so uniformly distributed that the cluster has a spherical

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shape with a decreasing stellar density as one recedes from the center of the cluster. For every star that approaches the center of the cluster another star recedes, so that the general appearance of the cluster remains unaltered throughout the ages. If such a cluster has a radius of ten parsecs (33 light years) and contains one hundred thousand stars of the same mass as our sun, and these are conservative estimates, it would require ten millions of years for a complete oscillation of a star, forward and backward, across the cluster; and many thousands of such oscillations would have occurred before the exquisite symmetry of these clusters would have been attained. As we have no reason for supposing that they were all started upon their careers simultaneously, nor that they have just arrived at the state of equilibrium, it is hard to escape the conclusion that some of them, at least, are hundreds of billions of years old. Yet, notwithstanding this great age, none of them exhibits signs of decadence. They seem to be neither youthful nor senile; their state is one of vigorous maturity.

As for the galaxy as a whole, it has been remarked by Jeans that if the gravitation between the stars were suddenly annihilated the effect of this annihilation upon the motions of the stars would be imperceptible even after the lapse of ten millions of years, so slowly does the gravitational attraction of the galaxy affect the motions of its individual members. Assuming that the radius of the galaxy is two thousand parsecs (6,600 light years) and that the average velocity of the stars is 40 kilometers per second, and these are the ordinary assumptions of the astronomers; assuming further that the galaxy is neither expanding nor contracting, and this is a pure assumption, as we have no definite knowledge on the subject, then the total mass of the galaxy is slightly greater than nine hundred million times the mass of the sun. Assuming that there are this many stars (some of this matter, at least, is in the form of nebulae) within the boundaries of the galaxy, then some other star will approach our sun as close as the orbit of the earth on an average of once in a million billion years. These close

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encounters are fundamental events in the dynamics of the galaxy for they alter radically the distribution of the motions of the stars and bring about that particular type of chaotic distribution of motions that is necessary for a steady state. The studies of Charlier and Jeans indicate that the steady state has not been attained in the galaxy, for in the steady state we should not have the phenomena of star clusters, star clouds nor star streaming. But notwithstanding that the steady state has not been fully attained, their conclusions are that the galaxy is well advanced towards a steady state. It is not necessary, of course, that two stars should approach as close to one another as the earth is to the sun in order to affect their mutual motions, and more distant encounters are much more numerous. But Jeans has shown that it takes the more distant encounters forty thousand millions of years to produce a cross velocity of one kilometer per second, and he agrees with Charlier that a cross velocity equal to the velocity of the stars would require a million billion years.

These results are not sufficient to enable us to compute the age of the galaxy but they are sufficient to indicate something of the order of magnitude of its age. It can hardly be less than thousands of billions of years and it seems much more probable that it is of the order of millions of billions of years. These figures are startling and would doubtless leave us in a somewhat skeptical frame of mind were it not for the fact that we have been somewhat prepared for their reception by the equally startling penetration of the astronomers into the depths of space. It has long been a commonplace among them that the galaxy is a physical unit so great that it takes light from fifteen to thirty thousand years to measure its diameter. Even though we bear in mind that light travels three hundred thousand kilometers per second and that there are over thirty-one and a half millions of seconds in a year we appreciate but faintly the stupendous scale upon which the galaxy is built—it is roughly a billion times the size of the earth's annual orbit about the sun. It is certain that we cannot reflect

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upon such a magnificent organization without being prepared to grant that the time-scale required in its building is equally magnificent. The apparent motions of the stars in a million years as seen from the earth is less than the familiar terrestrial motions going on about us in a single second, and on such a scale it would require over two million billions of years to correspond to a single life time of three score years and ten. Such an analogy, of course, is useful only in so far as it is helpful in maintaining our sense of proportion.

Although the geological evidences do not carry us as far back into the past as do the dynamical ones, nevertheless they are extremely valuable in that they assure us of the steadiness of the sun's light and heat throughout the geological record. The dynamics of the stellar systems deals only with the distributions of the stellar velocities under the action of gravitation, and it is quite immaterial in these studies whether the stars are hot or cold. If the contraction of the stars were the only source of stellar heat, in a few hundred millions of years the stars would all be dark and relatively cold bodies, but the distribution of the velocities would go on just the same. Eventually, that is to say after the lapse of a certain number of millions of billions of years, a steady state of motion will have been practically attained whether the stars continue to be incandescent or not, and so far as we can see the galaxy has an almost indefinite future before it after it has attained the steady state. But the evidences of geology, so far as they go, indicate that the state of incandescence is one of permanence, and this is confirmed by the complete lack of evidence of the existence of a cold and solid star.

The energy of the sun's radiation is about 1.2×10^{41} ergs per year. The radiation of the faintest known star is about one two hundredth of this, while the energy of such brilliant stars as Rigel and Canopus must be a thousand or perhaps ten thousand times as great. How can such prodigious energies be maintained throughout the vast intervals of time which the dynamics of stellar systems seems to indicate; and furthermore, what be-

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comes of this energy after it has assumed the form of radiation? Shall we think of it as spending an eternity upon a voyage which admits of no other incidents than a very rare reflection from or absorption by some physical object with a consequent reduction in wave length? Or shall we think of the radiant form of energy as but a phase in a grand cycle of existence? Obviously such questions are fundamental ones in a rational cosmology. We cannot hope to answer them directly from experience. The best that we can do is to frame our answers in accordance with some chosen system of postulates and to test them by their harmony or discord with our astronomical and our physical knowledge.

To most people it seems desirable to think of space as euclidian and infinite; the physical universe as infinite in extent, and such portions of it as come under our observations not essentially peculiar as compared with other portions; that our epoch of time has nothing essentially unique about it; and that, considered in a sufficiently large way, the physical universe is not tending towards some state which is inherently different from that with which we are familiar. Finally we recognize that the physical universe is organized into physical units, such as atoms and molecules, crystals and cells, stars and galaxies, each of which is an organization of smaller units endowed with a certain amount of energy and possessing its own peculiar properties. We have no reason for supposing that the electron is the smallest physical unit, nor, indeed, that there is any smallest physical unit whatever—and similiarly that there is no largest one. If we accept these postulates then our cosmology, if it is rational, must be consistent with them and at the same time in harmony with all of the known facts in every domain of physical science. As the hypotheses of physical science are rarely, if ever, in complete accord with all of the known facts, even when the field covered by the hypothesis is a relatively small one, it is hardly to be expected that the hypotheses of comology will be of a different character.

Consider for a moment a dilute solution of a chemical salt in water. If it were impossible to obtain concentrat-

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ed solutions in the laboratory, and if our observations were limited to a modest range of dilution, we might conclude that the state of the salt in the solution was but little affected by a change in the dilution, for such would be the results of our experiments. Actually, however, we are able to carry the concentration to a point where a rather abrupt change sets in and crystals appear. A similar error would result if our experiments in temperature were limited to but a few degrees. We would not recognize that a change in the physical state accurs when the temperature reaches a certain definite point.

These analogies should be useful to us in considering the effects of pressure. Such pressures as we can obtain in the laboratory affect the melting point, the rigidity and the density of a substance, but in general we think of a substance as being unaltered by pressure. One hundred thousand atmospheres is perhaps the upper limit of our experiments, and this is a very modest range as compared with the tremendous pressures that are developed in the interiors of the astronomical bodies by the force of gravitation. The pressure at the center of the earth can scarcely be less than three millions of atmospheres. For astronomical bodies of the same densities the pressure at the centers varies directly as the square of the radius; so that a planet of twice the diameter of the earth and of the same density would be subject to twelve millions of atmospheres pressure at the center. But if such a planet were made of the same materials as the earth—an altogether reasonable assumption— then the extra amount of pressure would result in an increase of density and therefore a still further increase in the pressure at the center. As we do not know the law connecting pressure and density we cannot compute just what the pressure would be, but it is certain, at least, that in astronomical bodies in the same solid or liquid state and composed of the same materials, the pressure at the center increases more rapidly than the square of the radius, provided the pressures are great enough to affect the densities, and the larger bodies will have greater densities than the smaller bodies.

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From an astronomical point of view the earth is a small body although it is the largest solid body with which we are acquainted. It seems to be near a border line. Planets and satellites smaller than the earth seem to be solid like the earth itself, and of smaller density, while bodies larger than the earth are largely if not wholly gaseous. From the point of view of pressure this would seem to indicate that the pressure at the center of the earth is approaching a critical pressure beyond which a solid or liquid state cannot exist. In other words a solid or liquid body much larger than the earth, and composed of the same substances, cannot exist on account of the great pressures developed in the interior. It is not reasonable to suppose that any organized structure, and the atom is known to be such, can withstand an unlimited amount of violence. We are not at liberty therefore to suppose that solid or liquid bodies can increase indefinitely in size, for the pressure at the center goes up faster than the square of the radius. Just what that maximum size would be we could not tell from any laboratory experiments on matter, but we can examine the various astronomical bodies in the solar system and this examination suggests that the earth is not far from the maximum size. The mass of Uranus is 14.4 times the mass of the earth and Neptune is 16.7 times the mass of the earth. If they were of the same density as the earth their diameters would be two and one-half times the diameter of the earth and pressures would rise to twenty millions of atmospheres. Actually, they are not solid bodies, for their densities are 1.44 and 1.09 respectively as compared with 5.5 for the earth. It will be observed that Neptune is slightly more massive and slightly less dense than Uranus. These facts imply that the mass of Uranus is greater than the maximum solid mass and consequently a large proportion of its mass is in the gaseous state. Neptune is slightly farther from the maximum point and a greater proportion of its mass is gaseous since its density is smaller.

Saturn is the next larger body with a mass 94 times that of the earth. If it were as dense as the earth its diameter would be 4.5 times that of the earth and its central pressure would be about 75 millions of atmospheres.

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Its density, however, is only .63 that of water and it is probably altogether gaseous.

This orderly relationship between the masses of the planets and their densities very strongly suggests that the pressure at the center of the earth is approaching a critical pressure at which the atoms begin to break down and their internal energies take the form of heat, a larger proportion of the mass takes a gaseous form and the mean density of the planet diminishes. With a sufficiently large mass the heat generated would be sufficiently great to make the whole mass gaseous, and this seems to be the case with Saturn.

It is evident that if all of the atoms at the center which are subjected to so great pressures should break down and yield up their internal energies simultaneously a violent explosion would ensue, and some such cataclysm may be the cause of temporary stars. But it is by no means necessary to suppose that this is the case. If we think of the atoms as in motion then the temperature and pressure at the center manifests itself to the individual atoms by the violence of their collisions. When we consider the very large number of atoms which enter into the problem and the great variety of their motions it is seen that the problem is a statistical one. The process begins when the pressure and temperature are what would be called "perfectly safe" by the collision of a pair of atoms which happen to be moving at speeds which are far above their normal speeds. The event is a very rare and unusual one and the heat generated does not noticeably affect the general mass. With increasing mass and the resultant higher temperature and pressure the extraordinary collisions become more frequent (though still excessively rare) and the temperature rises. With rising temperatures the permanent gases, hydrogen, helium, nitrogen, oxygen, etc., are driven from their chemical compounds and the atmosphere is increased at the expense of the solid mass. Eventually, that is for sufficiently great mass, the solid part becomes hot throughout and water exists only in the atmosphere. The importance of this will be appreciated by the fact

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that our own atmosphere would be increased three-hundred times if the oceans were vaporized. The earth would be covered with a thick mantle of clouds and the diameter of the earth as measured by an observer on some other planet would be noticeably increased and the mean density consequently decreased. Rising temperatures with increasing masses would give exactly the reverse of the condensation hypothesis; the solid mass would gradually pass over into the gaseous state. No explosion would occur if the body under discussion were built up slowly so that the process of adjustment was gradual and not by the necessities of the case a violent one.

While this change in the physical state is in progress there is a decline in the mean density since the conversion of a solid into a gas would result in a considerable increase in volume. But if a mass already gaseous should be still further increased, the resulting increase in pressure would result in a greater density for there would be no increases of volume due to the conversion of solids into gases.

If the assumption that Saturn is wholly gaseous is correct, then we should expect Jupiter, which is slightly more than three times as massive as Saturn, to be more dense than Saturn and this is actually the case, for the density of Jupiter is 1.25, or about twice that of Saturn.

If we had a planet three times as massive as Jupiter we should expect it to be more dense than Jupiter for the same reason that Jupiter is more dense than Saturn. But this process of increasing density with increasing mass could not go on indefinitely with gaseous masses any more than it could with solid masses. The heat generated by the high temperatures and pressures in the interior would increase greatly with larger masses until the expansive tendencies due to the heat generated just balanced the compressive effects due to gravitation, and there would be a second maximum in the densities. For still greater masses the expansive forces of heat would exceed the compressive forces and the density would again decline. We have no means of knowing for what

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mass this maximum density would occur—perhaps 50 or 100 times the mass of Jupiter. There is also some minimum gaseous mass which would become incandescent due to its generation of heat. It seems natural to identify this with the mass of maximum density although in reality the two may be different. This point of maximum density would then separate large gaseous masses into two classes, the dark gaseous and the bright gaseous or stellar. The sun is 1000 times the mass of Jupiter and it is in a state of intense incandescence, indicating that it is far beyond the point of maximum density. Its density is 1.4 or slightly greater than that of Jupiter.

When incandescence first appears in a growing star the mass of the star would be small and the luminescence would be feeble and of a reddish color. It would be a dwarf red star. As the star travels and gathers in the nebuluous material of space its mass increases, its color brightens, and the character of its spectrum changes through the series of types M, G, F, A, and finally to B if the mass increases sufficiently. Passing beyond the massive B-type stars, we arrive at the class of "giant" stars with small densities and high luminosities. These stars while relatively few are very conspicuous, and are found in all spectral classes. The return from the B-type of spectrum to that of type M with further increase of mass is probably due to the existence of a highly tenuous envelope surrounding the star, such as the sun's corona, due to radiation pressure. As this envelope increases in thickness with excessive and increasing radiation the direct light of the star itself, or perhaps better, the nucleus of the star, is cut off and an increasing percentage of the light radiated by the star comes from this relatively cooler envelope. The enormous diameters recently found by Michelson, 300 times the diameter of the sun for some of the giant red stars, seems to favor this interpretation.

It will be noticed that this arrangement of the spectral classes from the giant M-type, to the B-type, to the dwarf M-type stars is precisely the same arrangement as that made by Russell. The interpretation of the ar-

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rangement however is very different. Working under the Laplacian hypothesis that a star is a contracting mass of gas and that the energies of a star are derived from the contraction, Russell's arrangement is merely one of age; the young star is a giant and the old one is a dwarf. Under the present hypothesis the energies of contraction play a very insignificant role and the question of a star's age is discarded altogether. A star's energy is a function of its mass, and the energy is derived from the breakdown of the atom itself due to the excessive violence of the conditions imposed upon it by the increasing gravitational stresses.

According to the current concepts of physics the hydrogen atom is composed of a nucleus with a positive electrical charge and an electron with a negative charge, the two charges being numerically equal, and the electron in very rapid orbital motion about the positive nucleus. The atoms of the other elements are built up of hydrogen atoms suitably welded together. The electrical field, at a distance which is great as compared with the size of the atom, is therefore neutral; and likewise matter in a normal state is electrically neutral, since it is composed of equal numbers of positive and negative units. In the immediate neighborhood of the atom, however, the electric field is rapidly oscillatory, and the property of mass is due to the electric charges. Under the conditions of extreme temperature and pressure such as must exist in the interior of a star, a large number of the atoms must be disintegrated and resolved into free positive nuclei and negative electrons. Doubtless these combine to form atoms which exist for an instant and are then disintegrated, but occasionally a positive nucleus and a negative electron meet in a head-on collision and the two unite as though the nucleus was buried deep in the electron (the diameter of the electron is 2000 times the diameter of the nucleus). The resulting physical unit would not have the properties of an atom for there would be an exact super-position of the electrical fields, and the property of mass, at least in the gravitational sense, would disappear. The high speeds

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with which the electrons are known to move suggests that at the instant of collision the electron would be moving with the speed of light, and under this assumption the kinetic energy at the instant of collision can be computed. It is found that if a gram of matter should lose the property of mass in this manner the energy liberated would be equivalent to five billion calories of heat, and the present mass of the sun would contain sufficient energy to last at its present rate of radiation five billions of years.

According to the present hypothesis, therefore, the energies of the stars are obtained at the expense of their masses, and if the masses were not somehow renewed the life, by which we mean the period of its luminescence, of a star would be limited just as certainly as it is limited under the contraction hypothesis. It is known, however, that vast regions of space are nebulous and it seems quite probable that all space is more or less nebulous. We have only to suppose then that the amount of matter gathered in by a star in its journey through space is equal on the average to the amount that it loses through the process of radiation in order to account for an indefinite duration of luminescence. It is not necessary to suppose that the mass of a star is constant. If it plunges through a richly nebulous region its mass will grow with relative rapidity and its rate of radiation will increase, but if it should wander for several billions of years in a region which was virtually empty it would decline in radiation and ultimately reach the point when its light was extinguished. But it would brighten up again when the conditions were again favorable and its life would be renewed. Periods of darkness and periods of luminescence might succeed one another indefinitely.

The ultimate source of the stellar energies is to be found, therefore, in the energies of the organization of the atoms of the nebulae, and not in their gravitational potential energies. Space would eventually be swept clean of its nebulosity by the stars if its renewal were not provided for in some manner. Indeed, it is evident that the origin of nebulosity is as vital a problem in cos-

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mology as is the energies of the stars, for the stars feed upon it in exactly the same sense that the cattle feed upon the grass of the fields. We have already assumed that the atom breaks down in the interior of a star, and that when a positive nucleus and a negative electron collide and unite their electrical energies disappear in radiation and a new physical unit appears which has properties different from the atom. In particular this new unit is not subject to the law of gravitation and it therefore parts company with the star. It has served its purpose and is now a waste product. If this assumption is correct then space must be more or less filled with such units. What role they may play in what we call "empty space" (really, it is not to be supposed that space is anywhere "empty") would be difficult to say unless perhaps they constitute the units of that unsubstantial something which we call the ether. They may transmit energy even though they possess no mass. Let us suppose that this is so and that these units are affected by the energy which is radiating through space. Then it may happen upon an excessively rare occasion when the conditions are just right that one of these units is separated again into the two parts which had originally united and it returns again to the atomic state. The properties of mass and gravitation are restored and a certain amount of radiant energy has disappeared—exactly the same amount which the atom had contributed to the radiation of some star.

It would be idle to speculate upon the details of this process of restoration. We know that the radiant energy of the sun builds up the organic molecules of the vegetable world from the inorganic molecules. The cattle feed upon the vegetation, and the molecular energies appear in the motions and activities of the animals. Sooner or later these energies again take the radiant form and pursue their journey through space. The waste products of the cattle, including finally the body itself, are scattered over the fields and through the air. Again they become inorganic molecules, ready upon some rare occasion to take up a portion of the sun's ra-

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diation and enter upon another excursion through the organic world. This process is familiar to us, but we know nothing of the process by which the radiant energy builds up the organic molecule. The assumption that it does so in some manner fits in with our knowledge of the facts in the case and we are content to leave the details for future investigation. So with the restoration of the atom. If such an assumption fits in with the facts with which we are acquainted we can leave the details of the process for future study.

We have already adopted the postulates that the physical universe is infinite; that the distribution of matter throughout space is uniform in the sense that the limiting density of any sphere, as the radius of the sphere increases indefinitely, is not zero; and that that portion of the physical universe which comes under our observation is not essentially peculiar. It follows from these postulates that the distribution of stars throughout space also is uniform in the same sense. If it be assumed further, as is quite commonly, often unconsciously, done, that radiation suffers no loss in its transmission through space, then the entire sky should be as bright and hot as the disk of the sun. The total amount of radiation which we would receive would not be affected by cosmic dust and obscuring nebulosity, for the only effect which these things would have upon the radiation would be to increase the wave lengths, changing the light waves to heat waves without any change in the total energy of the radiation. As it is a commonplace of observation that the skies are dark and cold it is evident that at least one of the above assumptions must be abandoned. We prefer to abandon the assumption that radiation suffers no loss in its transmission. The fact that there is no sensible loss in such distances as are encountered in the solar system is no deterrent, for these distances, great as they are, are very small where interstellar or intergalactic dimensions are under consideration.

The energy of radiation cannot disappear, however, without doing work, for the conservation of energy is a

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fundamental postulate. If we admit that the energy which disappears as radiation reappears as subatomic energy several difficulties are disposed of at once. Not only do we answer the question "what becomes of the energies which the stars are pouring so lavishly into space?" but also its antithesis "what is the origin of the amazing quantities of energy that are locked up within the atoms?" As long as the atoms were regarded as permanent and indestructible units of matter we had no concern as to their origin. They had always existed. But once we have attained the knowledge that atoms are organized structures, questions as to their evolution and dissolution at once present themselves. Their activities during their lively careers furnish materials for study to the physicist, chemist, geologist, and biologist, but at their birth and death the astronomers alone are present. Even to the physicist an atom is a tiny thing. It is much more tiny to the astronomer. Their numbers however are vast beyond conception. In a cubic centimeter of water there are 3×10^{22} atoms and in the entire solar system there are 6×10^{55} atoms. But so vast is the scale upon which the stellar systems are built that if all the matter in the solar system was distributed uniformly throughout the sun's share of space there would be 10 cubic centimeters of space for each atom, and relatively to their size the atoms would be as far apart as are the stars themselves. The density under these conditions would be 3×10^{-24} and it is doubtful, though perhaps not certain, whether a nebulosity so attenuated as this could be detected by any means with which we are acquainted.

The hypothesis that atoms are evolved by radiant energy implies that all space is more or less nebulous. While we do not have direct evidence that this is true, nevertheless it is known that the volumes filled with perceptible nebulosity are extremely great, ranging from the naked eye nebula of Orion to the most delicate nebulae registered on long exposed photographic plates. Undoubtedly much more would be discovered if our detective agents could be made more highly sensitive, but

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however delicate the means of detection might be we could only hope to detect the relatively brightest regions. In addition to the nebulosity that is luminescent we recognize a large amount of nebulosity that is not luminescent by its accidental projection upon a bright background. In addition to the many examples of this given by the astronomical photographs, there is a splendid naked eye example lying across the Milky Way near the star Deneb, which under brilliant skies may easily be mistaken for a cloud in our own atmosphere. Indeed, the more the subject of nebulosity is studied the clearer it becomes that perceptibly nebulous regions are very common, and it seems not at all improbable that all of space actually is more or less nebulous.

In addition to the correlation of the spectral types of classes of stars and their masses and densities which has already been discussed, a second correlation is known which is worthy of note. It is known that the average speeds of classes of stars increases steadily from the slowly moving massive type B stars to the relatively rapid type M stars, which as a class have the smallest masses. This correlation, which was very puzzling at the time of its discovery some ten years ago, is a natural consequence of the present hypotheses. If a star plunges into a richly nebulous region and thereby adds considerably to its mass, its spectrum will be pushed towards the B type for the reasons which have already been explained, while its speed will be decreased, the matter which is gathered in acting somewhat like friction. On the other hand a star which is consuming its mass more rapidly than it is adding thereto will increase in speed if it be granted, as seems natural, that its momentum remains constant. There is difficulty in this correlation only with the giant stars, which instead of moving slower with increasing mass seem possibly to move faster.* The exceptional masses of the giant stars and their relatively small numbers imply that they have penetrated into regions which are exceptionally nebulous. If these were regions of high potential energy, high velocities would of course be the natural result. It is useless however to

* The recent investigations of Seares indicates that this is not so.

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dwell upon this point—not only are the giants exceptional with regard to their masses, they may be exceptional also with regard to their velocities.

It will be observed that if the radiations of the stare are derived at the expense of their masses and if the masses are renewed by material gathered in from the surrounding space, then there is no necessary upper limit to the life of a star, nor to that group of stars which we call the galaxy. The long intervals of time which are demanded by the dynamics of the galaxy have a real significance. In particular, the close approach of two stars, which, on account of the limited time admitted into the discussion, has hitherto been regarded largely as an imaginary event now becomes an event of fundamental importance, for they are certain to occur in sufficiently extended intervals of time. If the distance from the earth to the sun be taken as the measure of a close approach then for any one star there will be such a close approach once in every four million billion (10^{15}) years on the average; and if there are a billion stars in the galaxy there should be such a close approach somewhere in the galaxy once in every eight millions of years.

The consequences of such a close approach have been very carefully studied by Chamberlin and Moulton, and forms the basis for the Planetesimal Hypothesis as to the origin of our planetary system. The splendid harmonies exhibited by this hypothesis in the domains of dynamical astronomy and of geology impress upon us the conviction that our own sun experienced such a close encounter some ten or twenty billions of years ago, and that our planetary system is the result of the encounter. If this conviction is justified, then planetary systems must be fairly numerous throughout the galaxy and they should exist in varying stages of development. As ten billions of years is a very short interval of time from a galactic point of view our planetary system must be relatively young. If the sun should plunge into a relatively dense nebulous region and add to its mass, so also would the planets add to their mass. In the course of time the sun would lose its extra mass by radiation while the planets would not. After many such experiences Jupiter and

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Saturn would acquire such large masses that they would approach stellar conditions. Their distances from the sun would diminish and the perturbations of the terrestrial planets would doubtless precipitate them into the sun. Our knowledge of the three body problem is not sufficiently great to say with assurance what would happen to Saturn, but if it too was thrown into the sun Jupiter and the sun would remain to form a binary star. Thus it seems reasonable to suppose that one final stage of a planetary system is a binary star, or possibly a multiple one. It is true that over one-third of the stars are binary or multiple, which is an unexpectedly large proportion on any other hypothesis; and the only other reasonable hypothesis as to the origin of binary stars, namely by the process of fission, has encountered apparently insurmountable difficulties.

If we grant that the sun and Jupiter have become a binary star by the above process, and assume futhermore that they enter into a richly nebulous region so that they become five times as massive as their combined present masses, then the period of Jupiter would be reduced from twelve years to thirty-three hours. Its orbit would be circular and we should have a typical short period spectroscopic binary, and the spectral type of the sun would be pushed up well towards type B. On the other hand, if the masses declined, the orbit of Jupiter would expand and become more eccentric and the sun would approach the later type of stars. These conclusions are in striking harmony with the known facts that spectroscopic binaries of type B are short period and circular, while the visual binaries belong to later spectral types and are highly eccentric.

Assuming that the mass of the galaxy is a billion times the mass of the sun and that it has a radius of 2,000 parsecs, a star at rest upon its borders would acquire a velocity of 46 kilometers in falling to the center. And conversely, a star near the center which has a velocity of 46 kilometers will arrive at the borders of the galaxy in about seventy millions of years, with its speed exhausted. On the other hand, a star near the center of the galaxy which has a speed of 80 kilometers per second

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will arrive at the borders of the galaxy in less than twenty-seven millions of years with a speed of sixty-five kilometers per second, and will leave the galaxy never to return. Such stars are called run-a-way stars, and more than fifty of them, perhaps, are known, with speeds as high as 300 kilometers per second and even higher. They tell us in unmistakeable terms that intergalactic space is not altogether devoid of stars which pursue their lonely way without attachment to any particular system. They are truly "lost Pleiads."

Let us assume that a large region of extra-galactic space has become nebulous by virtue of the radiant energy which has long been passing through it. Eventually, one of our "lost Pleiads" enters the region. It begins to grow in mass and to diminish in speed. If the speed is sufficiently reduced, the star will be unable to escape from the gravitational control of the nebula and it becomes permanently attached to the nebula. Other stars are caught and held similarly so that in the course of time a region that was purely nebulous becomes a cluster of stars. If the stars came from all directions at random the cluster would have little or no tendency to rotate as a whole, and it would finally attain the forms of equilibrium which we recognize as the globular star clusters. If we imagine a loosely connected series of such nebulous regions, each one of which in time becomes a star cloud by the capture of wandering stars, and if we assume that the whole mass has an angular momentum about the common center of gravity, it is easy to see how the mass added by the captured stars would make the clouds draw closer together and build up such a wonderful system of stars as we find in the galaxy itself. Indeed, as the region within the galaxy is still somewhat nebulous it is evident that the galaxy has not yet altogether lost its capacity for capture. Eventually, however, the mass will decline through the radiation of its energies. The gravitative control of the cluster upon its individual members will relax, the cluster expands until, one by one, the stars escape the group control and resume once more their lonely wanderings.

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Whether the hypothesis that forms the basis of the present discussion, viz: the organization and dissipation of matter through the agency of radiant energy, stands the test of time and of closer scrutiny, it is evident that the deductions drawn from it are not only in harmony with the system of postulates with which we set out but are also harmonious with the main outlines of our astronomical knowledge, and furthermore no serious discordances are encountered. It is certainly not necessary to regard the physical universe as a mechanism which is running down.

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SELECTING AND ENCOURAGING STUDENTS OF SUPERIOR ABILITY

WM. A. MADDOX, PRESIDENT, ROCKFORD COLLEGE

It may be said that we have one common interest at this conference, despite our highly specialized fields; we are all in search of brains, of superior ability among our undergraduates, and are at all times anxious to promote zeal for investigation, a deep interest in and craving for original and creative work. I have, therefore, determined as your official host to discuss briefly the one topic that I hope will reach you all.

The college as we see it is divided against itself. There are two worlds—that of the students with its multiple interests and increasing stimulations from society outside the college, and that world of scholarly attainments and intellectual ideals to which we ask students to turn. The college is, as President Meiklejohn has observed, primarily, a place of the mind, not of the body, the feelings, nor even of the will. It is a time for thinking, an opportunity for knowing. Against this intellectual interpretation there are two sets of hostile forces constantly at work, the practical demands of a busy commercial and social life, and within the trivial, sentimental and irrational misunderstandings of its own professed friends.

Students come to college for many reasons, they accumulate "credits" and talk of "cuts". They often ridicule Phi Beta Kappa and Sigma Xi as a grind's paradise, 90% average and a little more, which, to the eager-minded and especially the creative-minded, does not represent real intellectual attainment at all. Even the faculty encourages students to think that "student activities" must of necessity be extracurricula and non-intellectual—foot-ball, fraternities, etc. If education comes only through activity, then our very vocabulary tells us its own story; class-room, even laboratory work, is never referred to as "student activity".

These activities are certainly educative when made part of the scheme of things, but to summarize the advantages of the modern college in terms of a country

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club or an athletic club, a place to know men, make friends, improve one's too democratic manners, or even to summarize it in terms of lofty ideals of character and citizenship, is to continue to widen the gap between the world of the students and the world of the intellectual life. There is little doubt that we as instructors are responsible at times for a large part of the failure to get over the idea that the college exists to give a "fulness of life", to promote the intellectual life. We cannot afford to be pedants or give color to the comic papers' characterization of a college professor as a man devoid of human interests and lacking in that very "fulness of life" which we accept as our goal.

We deplore the lack of intellectual interests among undergraduates, but seldom wonder over the commonplaces, trivialities, uninspiring conversations, even cheap gossip we sometimes hear when faculties foregather for lunch or recreation. We can only recall the youthful eagerness and idealism of students we know to wonder why they should accept the spurious coinage of "shop talk" or be inspired by things that we are glad to lay aside as we do our working clothes. Intellectual interests must be vital or we have no right to ask youth to accept the disciplining apprenticeship to achieve them. It is possible that we have asked too much of them.

The fact remains that our generation has been faced with a problem of classifying students from kindergarten through college, for a leadership that our grandfathers did not dream of. We deal in numbers. We have many new types, a greater diversity of interests and abilities than in 1900. At no point in this process is the brilliant child given a real chance, in a scientific sense, to achieve leadership. Our curriculum in school and college is keyed to the mediocre or democratic "average". The gifted student is too frequently either not tried out or is allowed to loaf through his training period and come out without ability to use even his native resources. It is hard to accept the principle growing out of the modern science of individual differences: "Keep each student at his highest level of achievement in order that he may be successful, happy and good."

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But we are making mighty strides toward this goal in these later days as false conceptions of democracy become evident in American politics. We have too much government by feeling, too little expertness of leadership, and too little of what Tarde speaks of as "government by thought". It is no accident that Thomas Jefferson, the great exponent of democracy, was the father of the public school system from primary grades through the university. He saw the relation of "genius" and its training by the state to the kind of democracy that Anglo-Saxons would finally accept. In proposing in 1776 this educational system which we now have, he insisted that it was poor social economy to exhaust the resources of the state in educating the mediocre at the expense of the gifted. Genius was too important an asset to democracy to be neglected for the mass. In a letter to J. C. Cabell, Jefferson speaks of having written Adams of his proposal for "culling from every condition of our people the natural aristocracy of talent and virtue and of preparing it by education at the public expense for the care of public interests".

Jefferson did not think with some of us that grouping in schools on the basis of abilities and attainment was undemocratic. He did not make that error in judgment even in the day when few went to colleges, when the college was highly selective, at a time when he could not foresee the hordes of students pouring out of the "grammar schools" (high schools, as we now call them) and demanding of society "What next?". It is apparent that he repudiated the theory of laissez-faire that a good man will rise to the top in the educative process, and if he does not, so much the better for society. He feared the leveling process and recognized that ability does not guarantee attainment or right leadership in either school or society. A fundamental knowledge of human nature led him to anticipate modern psychology in holding that good taste, ideals, right habits of thinking or working with the mind presupposed brains, but also presupposed initiative, prolonged effort, persistence, hierarchies of mental as well as physical habits, and those "moral" traits of industry, integrity, courage, tact, co-operation, etc. If we are to

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develop common man to "a position of supreme collective control"— the goal of democracy in the United States, we must guarantee leadership by education in the schools as far as the student can be induced to go up the ladder.

Now granting the problem of the schools and its implications for American democracy, the practical consideration is: "What can we do about it?" Our first great care, of course, is to promote by our own scholarly attainments and enthusiasms a respect for the intellectual life. This is not the relatively simple task of the nineteenth century. "We did not pass our college days," says President Alderman of the University of Virginia, "amid the din of the gasoline engine and the jazz of the phonograph, and the allurements and excitements constantly on tap in movies and popular magazines without and the engrossing interest of athletics within, organized on a scale so grandiose and exciting as to tend to drive other topics from the mind . . . . . The effort to show them the glory of scholarship, the fruitfulness of culture, must be commensurate with the vivid influences surging about them and bearing them into other fields. Such effort is the outstanding task of the American college for the next generation."

The second care lies in the practical recognition of individual differences. If the measurement of promise of intellecutal and moral leadership has not been reduced by any method to a reliable basis, we, at least, no longer hold to the theory that, as Professor Seashore facetiously words it, "If the Great Creator failed to make all human beings equal, it is the business of the school to make them equal." Still much of our machinery does suggest our faith in it. It has been pointed out at Columbia University that the best students, if allowed to go at a speed commensurate with their interests and ability, do two or three times as much work in four years as the ordinary undergraduate. Some take both the A. B. and A. M. degrees in that period.

Professor Seashore observes that differences in capacity tend to increase in proportion to the complexity

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of the task; for example, there are greater differences in mathematics than in plowing. One hundred college students tend to conform to a normal distribution curve:

"Five students at one end can do more than five times as much as five at the other end."

"The next five at one end can do more than four times as much as the next five at the other end."

"There may be one or two who can do ten times the average output for the class, while one or two are quite certain to fail."

His suggestion is that we section our classes according to freshman entrance mental tests, rank in "prep" school, early class grades, or any other evidence of achievement. Then that we say to the student: "Indications are that you can do A, B, or C work, as the case may be, but such grading is accepted in a tentative way; it now remains for you to show where you belong." Promotion or demotion may follow as a result of his trial. The student is apt to find his true level as fair standards for quantity, quality, content and method of work are set up, a fair basis for praise and blame established, and a better morale because the student will feel more responsibility for himself, will feel his opportunity, his power, the reward of achievement, and the stimulus of competition. This is one device.

Another device is our new American system of working for honors, suggestive, as President Aydelotte says in his recent report to the National Research Council, of the older Oxford system. The Oxford system roughly provides for two groups in its colleges: (1) those who come for "honors" or intellectual achievement; and (2) those who do not, primarily. The B. A. degree is given to both, but, we are told, there is as much difference between the pass B. A. and the first honors B. A. as between our American B. A. and Ph. D. The honors degree may mean two or three times as much work and a better quality of work than the ordinary bachelor's degree. The Oxford honors man is not subject to lecture attendance, he is told upon what fields he will be examined, not what and how much to do, and he is not ex-

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amined until the end of the two years of his honors course. On examination, he is warned not to attempt to answer all questions in a second-rate manner, but as many as he can in a first-rate manner. "The honors student," we are told by President Aydelotte, "cannot profitably be taught by the same methods as the ordinary man. He will not need the same careful day to day assignments, the same weekly and monthly tests, or the same requirements for attendance at classes. A part of the value of his work will come from the independence and initiative which are cultivated in the doing of it. He should be given larger tasks and longer time in which to do them. If he has individual instruction it should be in the nature of help in the difficulties which he, the student, has encountered; he should take the responsibility for his success and should be allowed to face squarely the task of working out his own intellectual salvation. Classes and lectures should exist for the benefit of the honor student, not the student for the benefit of the classes. He should enjoy as much freedom as can practicably be allowed in the matter of attendance at lectures and in the methods by which he will work."

A third means to this end is the Selective Admission plans, notably Columbia's experiment with entrance mental tests as supplemental to the older Regents, College Entrance Board, and High School Records. Professor Coss of Columbia stresses our inability to measure adequately for classification mental capacity, until we more adequately define the thing to be measured. As it stands, he believes that mental tests have three times the relative efficiency of high school records in determining promise of success in college. Nowhere are we pinning our faith on I. Q.'s, as they may limit educability or classify too strictly mental calibre, but certainly there are many applicants who should never enter college, and yet the problem is not so much one of elimination of misfits or discovery of "sheer brains" as it is the discovery of the best means of firing our students with enthusiasm for creative scholarship.

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We have respect for Phi Beta Kappa and Sigma Xi, at least in the attempt of leaders in those organizations to make them count in the solution of this very problem, but we are not quite so sure of the average student's reaction if we follow the college comic papers. We are familiar with the student fallacy that people who stand high in their classes are "grinds" and do not succeed in life. Students do not take the trouble to make a study of Who's Who and other biographies to find that there is a tremendously high correlation between success in life and Phi Beta Kappa in college. The shortcomings of our national honor society lie in the fact that they recognize attainment too late in the course and too late to increase the number of possible Phi Beta Kappa's. Just to make Phi Beta Kappa or Sigma Xi is not enough to stir the imagination of the freshman. Either these societies (at least Phi Beta Kappa, as I know little of Sigma Xi) must change their base somewhat or new honor societies must come to help select able students at the beginning of their course and stimulate and encourage them throughout.

Three years ago we founded such a society at Rockford known as the Socratic Society, organized to appeal primarily to undergraduate interests. At midyear, students of superior attainment and promise are elected from all four classes, particularly the freshman. Three elections during the four years in college make one a permanent member. The standards of scholarship are as high as Phi Beta Kappa. A formal initiation and ceremonial are held at midyear. The claims of the society are placed before the students by the students themselves each year at a special fall convocation. Rockford, it may be said in passing, also attempts to recognize achievement in the appointment of student assistants in the various departments and in the use of a large student aid fund and in a number of other ways common to all colleges.

This matter of a reward and recognition is perhaps the most fruitful field for study in this connection. In the old days when colleges were small, personal contact

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was, and in the few small colleges of today is still the great means of accomplishing many of the objectives I have mentioned, but most institutions are no longer small and the majority of students in them have little chance for personal contact with the able and great scholars of their institutions. The tendency has been too great in recent years for the great men of the staffs to give over their teaching to the teaching apprentices of their departments, especially in the under-classes.

The public hears more of the "student activities" referred to above than of scholarly attainment. For years I have heard people ask why intellectual achievement in the colleges should not receive the same publicity that distinction in athletics does. Of course, athletics are social and recreative, but there is really no answer, except that it does not. But it is possible to make creative or constructive scholarship more competitive, less individual, as is the honors system at Oxford—a matter of real community or college struggle for record. As athletic teams fight for scores, the Oxford honors system has the effect of intercollegiate contest among its twenty-two colleges.

In conclusion, it may be said that a great deal is being done toward the solution of this great problem, that it has been talked about periodically for a great many years, but that the constantly increasing numbers have made the situation more critical than it has ever been. Culture and democracy are not necessarily antagonistic, but they tend to be. Our great institutions of necessity have to lower standards. Formal instruction, systematic work, is good for a large group of our college population, but many bright students have to fight the limitations placed on their imagination, creative powers, and originality by the very organization necessary to many of their fellows. And it is our business to search out these very students of high ability for it is they who will pay society's dividends on our university investments.

Professor George W. Stewart of the University of Iowa, who spent last spring studying this whole question in sixty-seven colleges of the middle west, found a wide-

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spread desire to effect something in this field and some pessimism over the possibilities of doing more than we are doing. To give the suggestions that he has to make is perhaps the best way for me to close this survey, for, as he says, "the problem in each college must be approached in the spirit of finding the most effective recommendations and activities for that particular college." He recommends a committee on attainment, or what we might call a committee for the promotion of scholarship and the encouragement of creative, constructive, independent work. The activities, he points out, of such a committee should be:

1. To prepare an inventory of present methods for detecting and encouraging students of superior ability.
2. To prepare annual recommendations to the faculty.
3. To increase the effectiveness of student honor societies; to guide students of high ability in the first two years; to organize a study of the senior students; and to co-operate with outside agencies.

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SOME PHENOMENA IN A DYING LAKE

MELVIN A. BRANNON, PRESIDENT, BELOIT COLLEGE

The purpose of this discussion is to bring to the attention of this Academy some of the salient findings associated with the biological studies of a lake which is rapidly disappearing in the glacial drift regions of North Dakota. The latitude and longitude of this lake are 48° north and 98° west, respectively. The average annual range of temperature is from 35° below zero in winter to 95° above zero in the summer. Ice a meter or more thick forms in the winter. Winds with a velocity of 20 to 35 miles per hour move over the lake during many days in the months of July, August, and September. They cause a rapid lift in vapor pressure on the water surface and consequently evaporation is very high during the summer months.

The territory from which Devils Lake receives its water is an inland drainage basin. There is no outlet from this lake other than that afforded by evaporation. The result is that its specific gravity has now reached a point where the water contains 1½% solution of the salts of lime and magnesium. These salts are chiefly in the form of carbonates and sulphates.

Dr. Warren Upham made a definite study of this inland drainage basin in his work on glacial lake Agassiz. The following quotation from his report is of interest:

"Through the past hundred years maximum and minimum stages of the great Laurentian lakes have alternated in cycles of about a dozen years, during which comparatively scanty average rainfall for several years was followed by an unusually abundant rainfall. These fluctuations are similar to those just noted in the rainfall of North Dakota. Besides such short cycles important secular changes of the mean annual precipitation in this State, occupying considerably longer periods, have caused remarkable changes in the levels of numerous lakes which have no outlet."

"Devils Lake thus shows evidence of having attained, about the year 1830, a level of sixteen feet higher than

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its low stage in 1889, reaching at or near the former date to the line that limits the large and the dense timber of its bordering groves. Below that line are only smaller and scattered trees, of which Capt. E. E. Heerman informed me that the largest found by him and cut a few years ago had fifty-seven rings of annual growth. Within the twenty-five years since the building of Fort Totten, this lake has fallen nine or ten feet, and it has fluctuated four feet under the influence of the changes in the average annual precipitation of rain and snow during the past dozen years."

"The high stage reached by this lake about sixty years ago appears to have been limited by an avenue of discharge eastward into Stump Lake, which rose at the same time to within about three feet of this height. The latter and smaller lake, receiving no large tributary and lying in a basin that nowhere extends many miles from the lake, was prevented by evaporation from rising quite so high as Devils Lake, which, during abundant years of rain and snow, receives a large tributary, the Mauvaise Coulee, draining a broad area that stretches sixty miles northwestward to the Turtle mountains. The outlet of Devils Lake into Stump Lake was nearly due eastward from Jerusalem, situated on Lamoreaux Bay at the most eastern portion of the entire lake shore. With an overflow at this point, Devils Lake may many times have been raised to this beach by periodic variations in rainfall during the many centuries since the ice age."

"At the time when the last ice sheet retreated, however, the confluent water of Devils Lake and Stump Lake were raised to a shore line which now has a slight ascent from west to east, lying twenty-one to twenty-five feet above the low stage of Devils Lake in 1889. This shore is traceable around both lakes, passing above the watershed that now divides them."

Our 1922 records now show that the level of the lake has fallen about eighteen feet since June, 1883, when it was 1439.08 feet above sea level, the reading at present being 1421 feet above sea level. The recession of the water during the eighteen-foot vertical drop in thirty-

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nine years has greatly diminished the area of the lake. It is not to be inferred that the eighteen food lowering of the surface has been a constantly progressing process. Some years the loss was through the heated summer months and was restored by the melting snows and spring rains. In some cases the low levels have been replaced by higher stages lasting for one or more seasons.

The physical factors which accompany the disappearance or dying process of a lake are numerous. Naturally the most notable features are the lowering of the water level, the emergence of islands, the appearance of land projections and the final separation of the main body of water into lesser basins.

With the continued evaporation of water there is, of course, the attending increase in specific gravity and the lift in osmotic pressure registered by the solutes upon living organisms within the water.

There is a diminution of luminosity and a precipitation of mineral and organic matter as the lake grows older and the dying process advances.

With the development of the shallow basins and the comparative shallowness, even in the deepest part of the Lake, the effect of winds and modification of temperature, distribution of the gases, oxygen, carbon dioxides, and nitrogen are more rapidly modified and adjusted than was the case in the younger and deeper lake.

The chemistry of a dying lake is associated specifically with a concentration in the mineral content and the readjustment in proportion of carbon dioxide and numerous other substances in solution.

The physical and chemical changes incident to the drying up or dying process in Devils Lake are apparently going forward quite rapidly at this time. In 1914 the average collections of water from various parts of Devils Lake showed that it was .94 of 1% saline. During the last eight years, due to the excessive evaporation and the attendant concentration of lake water, the salinity has increased to 1½%. This indicates a rapid concentration of mineral solutes and complicates still further

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biological questions which are of particular importance in the investigations of dying lakes.

The chemical composition of the water in Devils Lake has been determined many times during the twelve years that the Biological Laboratory staff has been studying the life of its waters. In 1910 our chemists gave the following report:

TONIC COMPOSITION

	Parts per million
Calcium	4.0
Magnesium	603.9
Sodium	2908.8
Bicarbonate Ion	708.0
Carbonic Acid Ion	126.0
Sulphuric Acid Ion	6098.4
Chlorine	1177.0
	11626.1

HYPOTHETICAL COMBINATION

Calcium Bicarbonate	2.4
Magnesium Bicarbonate	846.9
Magnesium Carbonate	177.1
Magnesium Sulphate	2029.9
Sodium Sulphate	6625.9
Sodium Chloride	1177.0
	10859.2
Total residue	12429.0
Silica	12.2
Iron Oxide plus Aluminum Oxide	4.0

Considerable quantities of organic matter and of insoluble matter were present. The water stood for a long time in a warm room. It is quite possible that some of the calcium bicarbonate was decomposed in this way, precipitating out calcium carbonate. This may account to some degree for the small amount of calcium found.

Devils Lake is shallow, twenty feet being its maximum depth. High winds churn the water frequently during the spring, summer, and autumn. Obviously the oxygen, nitrogen, and carbon dioxide would have a continual and rapid vertical distribution during the open season. Analysis of gases at different levels of the lake in 1911 gave the following readings:

1911			Depth	
June 1	Surface	7.49 cc of O_2 per liter of water—	13′ level	5.76 cc
June 29	"	5.39	14′ "	4.22 "
July 22	"	5.55	13′ "	3.46 "
July 31	"	5.46	15′ "	4.64 "
Aug. 7	"	5.40	Bottom 18′	2.14 "

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For the purpose of this particular discussion, the changes in the physical and chemical factors within a dying lake have particular importance biologically. The student of physiology dealing with plankton, filamentous algae, higher plants, higher animals, and the bacteriological organisms inhabiting the waters of a lake which is gradually disappearing, has an extremely mixed culture, containing many varieties of organisms, all of them undergoing seasonal and periodic change in number of any one form and in the proportional numbers among all forms. This great natural culture solution affords an opportunity for studying permeability, osmotic pressure, and the limits of adaptability of the organisms as well as a study of their reactions upon the medium within which they are contained. An illustration of these points may be had in the reaction of every organism which can live in the waters of a gradually dying lake whose salinity is continually advancing. The reactions of the organisms which survive afford some explanation perhaps for the absence of organisms which cannot survive. Professor Oltmanns made some very interesting studies of the various factors involved when he undertook to transfer certain green algae to water of higher salt concentration.

He says: "Spirogyra and Chara withstand a salt concentration of 0.5%. However, they are unable to withstand a 1% concentration because they cannot take in sufficient salts to raise temporarily the osmotic pressure of their cell sap. In other words, they are unable to bring about proper osmotic alterations rapidly enough to adapt themselves to the saline habitat."

Prior to 1889 the waters of Devils Lake has been populated with vast numbers of great northern pike. Authentic reports state that these fish were taken out in carload lots by those who speared them through the ice. For some reasons unknown to the layman, these food fishes which appeared in actual shoals during the years preceding 1889, suddenly vanished.

The three prevailing explanations of the pseudo-scientists were that the water had become poisonous, that insufficient food was present, and that some disease had caused the fish to die. While any of these might have

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been true, a study of the biological situation led to the belief that no one of them had the slightest relation to the sudden disappearance of this important food supply formerly secured from Devils Lake. What really had happened was that due to the isolation of the Devils Lake waters from fresh water lakes to the north having a slightly higher altitude, with the increased dessication during the arid years from 1885 to 1890, the water level in the fresh water lakes and in Devils Lake had fallen below the bottom of the creek or coulee channel which connected them. The great northern pike apparently followed the habits of the ocean salmon and migrated in early spring, passing through the connecting coulee to the sweet water lakes north, where shallow fresh water beds produced large areas of favorable spawning ground, thus insuring the propagation and continuance of the swarming pike. In the autumn, it was reported that the pike migrated from the shallow sweet water lakes to the deeper, and therefore better protected winter habitat of Devils Lake. When the connecting coulee dried up and Devils Lake became segregated from the spawning grounds in the sweet water lakes, reproduction of pike ceased. Obviously, if an organism is prevented from propagating itself, it soon vanishes from the earth, as did the wild pigeon.

Following the studies of the physiographic, physical, and chemical changes, certain experiments were initiated in the adaptation of higher plants and animals to the water of Devils Lake. These organisms were taken from bodies of sweet water within the neighborhood of Devils Lake, or secured from the United States Fish Hatchery. Experiments were tried with yellow perch, rainbow trout, bull heads, and other material available for experimentation. Perhaps the following details of a few experiments may be sufficient for this report of the physical reaction of higher organisms in the water of the dying lake:

Prior to the initiation of our studies at the Biological Station in 1909, many attempts had been made to restock Devils Lake with fish. Much private, municipal, and federal money had been spent in fruitless efforts to secure

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this greatly desired result. A study of the experiments which had been made by preceding workers offered small hope of success provided their procedures were closely followed. However, to make quite sure, a duplication of the former experiments was made with the result that those in charge of the Station work became convinced that there was no hope of success in following the lines of procedure formerly instituted. The problem was entirely too complex for any guess work or merely empirical procedure. In other words, it was manifest that successful culture and distribution of fish rested wholly upon ascertaining, first, the physical, chemical, and biological facts which entered into this very complex problem. As already indicated, these facts could be learned only through analyzing many hundreds of collections, carrying forward many experiments, and determining the limiting factors of the life already present in Devils Lake.

After determining that there seemed to be no inhibiting toxic agents present, that there was ample oxygen in the water and thousands of tons of available fish food, an effort was then made to determine whether a successful method of introducing fresh water fish into Devils Lake might be established by following a procedure similar to that which characterized the natural situation in former years. Consequently, a series of tanks was built in the Biological Station and they were supplied with special devices for adding oxygen to the water as it was pumped into the tanks.

Yellow perch and other forms experimented with would frequently show great distress and die within an hour when placed in shallow water at a temperature of 24 degrees C., whereas when the temperature was kept lower, from 17 to 20 degrees C., they appeared to be quite comfortable. In view of this, the water was introduced into the tanks at 17 to 19 degrees C. The aerating devices assured a gas content of 4 to 6 cubic centimeters of oxygen per liter. Yellow perch, steel-head trout, large-mouthed black bass, pike, and some other varieties of fish were used in the experiments conducted during the summers of 1911 and 1912.

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It was further found that the fish taken from fresh water lakes and transported 100 miles or even a shorter distance required some time to recover from the effects of transportation. Usually the fish which were weakened or injured through transportation would be eliminated during the first four to six days they were in the experimental tanks. At the expiration of this period, Devils Lake water was mixed with the water from the deep well in the portion of one to three. At intervals of two to three days, the proportion of Devils Lake water entering the tanks was increased until the wholly undiluted Devils Lake water was supplied to the experimental tanks. Under average conditions, with average shipments, it was found that this process of increasing the per cent of Devils Lake water could be completed within ten to twelve days. After the fish had been retained in these experimental tanks for a period of one to three weeks, they were transferred to anchored floating fish pens in order that their condition and behavior might be kept under observation for several weeks. It will be noted that the specific gravity of the Devils Lake water to which they had become adjusted in the acclimatizing experiment was 1.019. It is to be further observed that they were taken from water having an osmotic pressure of .03 to .04 of an atmosphere and they were placed in water having an osmotic pressure of 4.6 atmospheres. As previously stated, it was found necessary to keep the temperature of the tank water within the range of 17 to 19 degrees C., and to maintain an oxygen content not lower than 4 cubic centimeters per liter in order to secure the best results.

The transfer to the floating fish pens in the lake was more successful if it was done in the evening or during cloudy days, presumably because the temperature of the lake water was lower at those times than during periods when it had been subjected to the heat accompanying bright sunshine for some hours. Floating tanks were found to be far more satisfactory than submerged ones. The latter gathered too much floating debris and sand which, of course, would interfere materially with the respiratory apparatus of the fish placed in the submerged pens.

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Of the fish used, the yellow perch and steelhead trout proved the most resistant and satisfactory. Excellent results were obtained during the summer of 1911 in the tests with these two varieties. However, it seemed desirable to postpone publication until the experiments could be extended and the results verified by subsequent cultures. Consequently, early in the season of 1912, large reinforced concrete tanks were built and the experiments were conducted out of doors. Yellow perch were gotten again from the nearby lakes and Turtle Mountain region and passed through the control experiments, duplicating those of 1911. When the perch were transported properly and the acclimatizing experiments conducted with care, the percentage of loss was only 10 per cent, including the losses which came from injuries in transportation and failure to recover from the fatigue of the trip. It was found that from 300 perch received on the 19th of July, 246 were vigorous and absolutely normal when examined in the floating fish pens on August 12. The following year we recaptured yellow perch from Devils Lake, proving that they had survived the change one year.

In the latter part of May, 1912, a shipment of rainbow trout was received from the United States Fish Hatchery at Spearfish, South Dakota. They were placed in tanks containing well water on May 22. There were many fatalities during the month of June, due to mechanical troubles with the pumping plant of the station. On July 3, the trout which remained alive from the shipment received six weeks before were transferred to the tanks outside of the building into which there was introduced a mixture of lake and well water. An exceedingly high temperature during the 3d and 4th of July raised the temperature of the upper lake water 10 degrees above that which had been in the indoor tank water. Furthermore, they had been placed in newly built concrete tanks from which soluble salts had not been sufficiently removed by long continued washings with the fresh or well water. The result was that out of 100 placed in the tank at this time, 40% died within 36 hours. There was a lowering of the oxygen content of the water, a great increase in

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temperature, and an increase in the soluble materials in the newly built tanks, a combination which was serious for so delicate a fish as the rainbow trout. On July 17, it was deemed that the increase of Devils Lake water had been carried to a point where undiluted lake water might be used. No serious results were noted.

These fish were fed macerated liver. Most of them fed freely and were active, thriving, and growing. Some of them refused to eat from the beginning of the experimental period, and did not grow, but remained in an abnormal condition throughout the entire time they were kept in captivity. On August 14, 48 were transferred to the floating fish pen in the lake. Several of these trout were diminutive and represented the starved, unnourished members which had survived. Two weeks later, on August 29, 34 rainbow trout, after 98 days of experimental work, were turned into the lake. They had grown from 2½ centimeters to 5½ centimeters. They were exceedingly active and vigorous and seemed to be wholly adjusted to their new surroundings. While the experiments with the rainbow trout were attended with far greater losses than was the case in the experiments with the perch, the final results indicated that we were approximating very closely proper methods of acclimatization when we were able to save any of the exceedingly delicate rainbow trout and secure marked growth and great vigor and activity in the stock which were turned loose at the end of the 98 day experiment.

As previously stated, to the plant and animal physiologist it is obvious that biological studies in the waters of a dying lake afford conditions not only for interesting adjustments within the cells of the organisms experimented with, but there is afforded also a remarkable opportunity of investigation for all kinds of cellular biology. This is particularly true in the study of phyto-plankton. The changes in the membrane, the plasmolysis, and the gradual acclimatization in acquiring the "euryhyaline habit", as Professor Oltmanns expresses it, may be studied with the one cell organism in a remarkably successful manner. While one does not attempt to draw general conclusions from a few isolated experiments, nevertheless he is con-

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vinced that the rich and rare opportunities for the study of the physiology of multicellular organisms, a study even of such recondite subjects as ductless glands and internal secretions in multicellular organisms, are all of them illuminated, or may be illuminated, by a study of the unicellular and multicellular organisms which inhabit the waters of a dying lake prior to the time when the higher plant and animal life vanished because of the over-concentrated solutes in the water.

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SCIENCE VERSUS EMPIRICISM IN PUBLIC HEALTH WORK

ISAAC D. RAWLINGS, M. D., DIRECTOR, ILLINOIS DEPARTMENT OF PUBLIC HEALTH, SPRINGFIELD

Definition: The Century Dictionary and Encyclopedia gives as one of the definitions of empiricism—"an undue reliance on mere individual experience".

In this sense, empiricism as the basis for effective public health work is often inaccurate, inefficient and expensive when measured by the better results obtained through the application of exact scientific information.

The French in endeavoring to build the Panama Canal made use of the empiric knowledge then existing in attempting to combat the hotbed of pestilential diseases which they found in Panama. It is said that each crosstie in the Panama railroad, which is many miles long, is a monument to the death of some Frenchman sacrificed in the unsuccessful attempt to build the Panama Canal.

This failure in a large measure was due to the use of methods for control of diseases founded on inaccurate unscientific experience.

Contrast the thousands of deaths, the enormous sick rate, and this failure based on the false deductions of empiricism with the brilliant success of the American attempt. During the years which had elapsed between these two attempts to construct the Panama Canal, empiricism had yielded to science. Gorgas had accurate, exact, scientific facts as to the etiology, mode of spread and true methods of prevention and eradication of these pestilential diseases, instead of the exploded, mistaken theories used by the French based on supposed facts, the result of the deductions of experience.

Again today, contrast the status in yellow fever control with the appalling situation existing in 1878 under the empiric methods in yellow fever epidemics as related in the following quotation concerning a southern city:

"Less than one short year ago, there was enacted a tragedy which has no parallel in the annals of this country, and but few in the annals of mankind; a tragedy the

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principal actor in which was the insatiate monster, Death. Along these streets and in these homes the heavy shadows of his dark wings fell, sweeping often into one common grave whole families, from the gray-haired sire down to the little babe which nestled in the crib. The very atmosphere was thick with his poisonous shafts, and it seemed inevitable that this beautiful and thriving city of this great valley was doomed to witness the extinction of her every son and daughter. Here, the wail of anguish and suffering went up from childless parents, parentless children, husbandless wives and wifeless husbands, until it touched the great humane heart of Christendom, and the fountains of charity were opened up, and a broad, steady stream flowed from every section; often coming in the form of a brave, philanthropic man, a fearless, devoted woman, or in limitless quantities of money or supplies to meet the wants of the suffering and to sustain the strength of the well. It was here that the heroes and heroines were born; it was here that they died."

Compare this death and destruction, together with the panicky flight northward upon announcement of yellow fever in the South and the attending shotgun quarantine and drastic inspection with enormous expense and destruction of property, with the sane and calm measures of today, consisting of screened isolation of the yellow fever patient and the destruction of the mosquito, with no thought of panic or extensive quarantine because accurate, effective, scientific methods of control now exist. Truly, scientific knowledge simplifies health measures.

In malaria, too, we know today that this disease is not a visitation either of providence or noxious gases but rather a visitation of a certain variety of mosquito. To banish this disease, science has shown it is necessary only to abolish the breeding places of this variety of mosquito. In the diagnosis of malaria, also, the old empiricism of the old style doctor with the confusion of typhoid fever, yellow fever and other fevers with malaria are a thing of the past, since the microscope reveals the blood picture and gives an accurate diagnosis of malaria.

At present in public health work in progressive communities, the basis for the termination of diphtheria

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quarantine is the exact knowledge obtained through the examination of cultures from the nose and throat of patient and close contacts. Two cultures negative as to the diphtheria bacilli means safe to release. Where the release is made on the experience basis of a twenty-one day quarantine since the onset, some cases are held longer than is necessary, while others are released before contagion is gone. Thus we have an accurate method replacing an inaccurate, unsafe one.

Again, the positive reaction of a Schick test is a scientific indicator of a person's susceptibility to diphtheria, and the permanent immunization with toxin-antitoxin of such a person thus positively proven to be susceptible to diphtheria is an accomplishment of science over the empiric fallacious procedures of former days in attempting active immunization of the individual against diphtheria.

Formerly, in our epidemiological studies, we were satisfied under empiric methods to say whether cases of typhoid fever during an epidemic came from water, milk or other food, but today we want scientific data as to exact source of the contamination of these, whether the food-borne infection came from a typhoid case or a typhoid carrier. Cultures and microscope can determine the exact source, and adequate quarantine will eliminate the person spreading the infectious material to the water, milk or other food. You thus scientifically stamp out your epidemic.

Formerly, on basis of experience, we refused to terminate any cases of measles in less than 16 to 18 days from date of onset. Today, scientific accurate data has revealed that the contagious stage in measles is over by the end of the third day following the appearance of the eruption, so we release the patient from quarantine in five days instead of holding him as formerly for 16 to 18 days.

The former public health procedure based on empiric data of quarantining all cases of cerebrospinal meningitis resulted in many useless quarantines, while the scientific and other data now obtainable through spinal puncture and microscopic examination permit us to

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quarantine only that infectious form of cerebrospinal meningitis due to the meningococcus and to exclude from a useless quarantine the tuberculous, simple and other varieties.

We need but recall the ravages, the panic and the feeling of helplessness of the populace in the presence of widespread typhus fever epidemics to get a vision of the blessings and benefits of scientific data to our people, to say nothing of the financial economy now that we know that by thorough delousing operations we will prevent and protect against this often fatal disease.

The allotted time does not permit us to cite other equally important victories of real science over former empiricism in connection with diseases in the realm of public health activities. Neither will time allow us to take to task the scoffers who declare no advance is being made in exact information and scientific data relating to preventive medicine as it concerns public health. Suffice it to recall the sense of security we all feel today, thanks to scientific contributions, as contrasted with the horror, ravages and panic of other days in the certainty with which epidemics of:—

(a) Smallpox can be controlled by vaccination.

(b) Typhoid fever can be controlled by sanitation, vaccination and quarantine of carriers.

(c) Yellow fever can be prevented and controlled by screening of patient and destruction of the Stegomaia mosquito.

(d) Malaria can be prevented and controlled by screening patient and preventing the breeding of Anopheles mosquitoes by drainage, oiling and other anti-mosquito eradication procedures.

(e) Asiatic cholera and Bubonic plague are prevented and controlled by accurate, definite, scientific measures.

The accomplishment of all of these and many other results spell victory of science over empiricism.

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STORED ENERGY

FRANCIS B. DANIELS,* THE PULLMAN COMPANY, CHICAGO

Sir Ray Lankester, in one of the interesting papers published under the title, "SCIENCE FROM AN EASY CHAIR," complains that "glib writers in various journals" "with a false assumption of knowledge" "pour forth" "twaddle" concerning science. It should be said that he puts twaddle in quotation marks, also, with the parenthesis "(if I may use an expressive term)". May not these "glib" journalists come back with a complaint that "glib" scientists, of high reputation for actual knowledge, do worse, in that they teach "twaddle" to journalists, that is, to people generally who are not specialists in science? Is not *stored energy* an example? It is taught to non-specialists by writers of high scientific reputation.

Energy is an important word in the technical literature of the science of physics. It is treated of as existing in two forms: kinetic and potential. In books written by scientists to attract, or edify, purchasers among the general public, *potential* often approaches in meaning, or is transformed into, *stored.* This meaning has had a curious effect. It has inspired flights of fancy which may, perhaps, be called poetry, in the sense of "imaginative language, or composition, whether expressed rythmically or in prose" (Webster). At the same time it has operated as a warning against venturing upon prosaic data. The following specimens are culled from "NATURE'S MIRACLES" (Gray, 1899), "MATTER AND ENERGY" (Soddy, 1912), "SCIENCE AND MATERIALISM" (Elliott, 1919), "CREATIVE CHEMISTRY" (Slosson, 1920), and "HISTORICAL GEOLOGY" (Schuchert, 1920):

"These great" coal "beds of stored-up sun-energy* * * warm our houses, * drive the machinery of our factories, * send the locomotives flying across the continents and the steamships over the oceans."

"Energy may sleep indefinitely * * *. In the potential form, in coal, it has persisted for untold ages; once released, heat is the sole ultimate product * * *. The power

* Died April 18, 1922.

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of sunlight and coal, electric power, water power, winds and tides do the work of the world."

"By burning the coal, the energy which has so long been locked up is given forth afresh in its original form of heat and light."

"All life and all that life accomplishes depend upon the supply of solar energy stored in the food."

In plants "the kinetic energy of sunlight is transformed * * * into the potential chemical energy of * foodstuffs. Animals * * * convert the potential chemical energy of foodstuffs into the kinetic energy of locomotion and other activities."

These flowers of rhetoric are uniformly unaccompanied by a reference to an observation, experiment or line of reasoning on which they are based, nor has diligent search been able to find such in any literature.

It is possible that the primary motor in all this is the phrase *conservation of energy*. We owe the phrase to a translator. Is it not an instance of unhappy scientific nomenclature? By those who are appropriately educated it is understood as the technical name of a transcendent generalization regarding the physics of nature. But if the phrase should happen to be without illuminating context, when seen for the first time by one not grounded in physics, he would be likely to feel the need of a dictionary, unless diverted by the fancy that it was from an advertisement of a patent medicine held out as preservative of human vigor. He might not take the phrase in a scientific sense, because of the idea that conservation implies design, which, as controlling nature, however religiously believed in, is not within the present reach of science proper.

But Conservation seems less questionable than Energy. "Capacity for performing work" (Webster) fails to satisfy. A recent translator makes Arrhenius say: "Everybody understands what is meant by energy." What Arrhenius might have said if writing in English, is unprofitable conjecture. Men of Science use English expressions such as these: "All forms of energy may be regarded as motion"; "Energy is motion"; The princi-

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ple of conservation of energy means that the total amount of "motion" in the universe, or system, "remains ever the same." But a little further reading shows that the meaning is not settled by such expressions. The same book reads: "All forms of energy may be regarded as motion", and there is a "species of energy, named potential energy, in which nothing is moving." The Century Dictionary defines kinetic energy as "energy in the form of motion", and potential energy as "energy existing in a positional form, not as motion".

The most universal illustration of potential energy is a raised weight. The reader may happen to have seen the quotation from Crabb, in the New Revised Encyclopaedic Dictionary: "With energy is connected the idea of activity." If so, he will be sure to ask himself what the activity is doing in the weight while remaining raised, and will be disappointed by not being able to find in the book which gave the illustration, or in any other, either an answer—which perhaps he would not expect—or so much as an intimation that such a question might arise.

Another frequent illustration of potential energy is a coiled watch spring. It is familiar knowledge that if a spring is of gas or rubber, heat is developed in the compression and absorbed upon the release. The reader who has no laboratory, but only books, would be much better satisfied with the illustration if it were accompanied by information as to whether similar heat phenomena attend the use of a metallic spring; also whether, in either case, the heat is adequate to the work. But nowhere is this question referred to.

Conservation of energy is the technical name of the generalization, or principle, that the amount of energy in an isolated system remains the same, that is, never changes in quantity. Carl Snyder ("The World Machine," 1907) says that "gravitation is a standing negation of such a concept". The raised weight illustration certainly induces the question: "Where does gravitation come in?" And if potential energy does not exist "as motion", the question arises whether a clear concept of potential energy can be consistent with an equally clear concept of the conservation of energy. The phrase *per-*

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petual motion would seem to be one that "everybody" would understand more easily than *conservation of energy*. It certainly would have been less likely to result in the difficulties attending *kinetic* and *potential*. It has been buried in derision, however, because connoting a machine designed to thwart a fundamental method of nature. But when used so as to include the smallest particles, as well as masses, it cannot be negatived—unless by gravitation, the nature of which, though the subject of a great amount of speculation, remains as much a mystery as ever. Professor Tyndall's description of heat as a "mode of motion" seems better adapted to a clear concept than the modern expression "form of energy".

Exception is not taken to the term *potential energy* in a school book. The pupil who really cares will become scholar enough to understand. The objection is only to its use without the support of explanation or reference in books intended for the general public. It seems to be responsible for *stored energy*. Possibly, also, it may mislead some who are educated in branches of science that do not involve general physics. An eminent, and genuinely scientific author, in such a branch, published the following:

"In animals the final products of broken down protoplasm are carbon dioxide, water, and a nitrogenous substance called urea. These products are called excretory products. The animal machine is unable to utilize *the energy which exists in the form of potential energy* in these substances, and they are removed from the body." (Italics mine.)

The italicized words are unnecessary. They are of the type termed, in legal phraseology, *obiter*. It was suggested to the author that they be omitted from later editions. They reappeared, however, though, to save his life, he could not have proved them, nor cited anything put forth as proof.

Stored energy is the present subject. By its mention the writer is forcibly reminded of the memorable words of the famous philosopher, Mrs. Prig: "I don't believe there's no sich a person."

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As the quotations indicate, carbon (in fuel or food) is the leading illustration of stored energy. The quotation of the powers that "do the work of the world" is from so prominent an author in the literature of science as Professor Soddy. Please observe that coal is listed and oxygen not listed. Then perform the concrete experiment. Perhaps you can do so well enough in your mind. It has been performed countless millions of times by an ordinary fire, and thousands of times in the laboratory. The chemistry is elementary. Compound (approximately) 12 weight units of carbon, ordinarily a solid, possessing no readily perceptible activity and incapable of combination without the application of external heat, with 32 like units of the most universally active substance known, oxygen, a gas, capable of combination whether cold or hot, and the result is heat and light and 44 units of a substance more obviously active than solid carbon and less obviously so than oxygen gas. The inference requisite to sustain the illustration is that the motion, or energy, manifested by the heat and light had, immediately before, been in the carbon and not in the oxygen. "Can you beat it?" Please pardon the slang.

The chemical weight units are of such class that commercial weights may be substituted, so that when you burn twelve tons of coal, or rather, of carbon in coal (plus the weight of the ashes, moisture and other irrelevant ingredients), you burn or consume thirty-two tons of oxygen, and besides the heat you were after, you produce forty-four tons of carbon dioxide, that goes up the chimney. The light that is also produced is in the same category as the heat, and need not be considered separately.

Carbon, in wood or coal, has the appearance of a solid possessing no life that can be detected at the woodpile or coal bin. Oxygen, on the other hand, is a gas, which has life that manifests itself by keeping us alive. Moreover, it is, metaphorically, an all-devourer. By devouring carbon it makes carbon dioxide, by devouring hydrogen it has made all the water of the earth, by devouring silicon, etc., all the granite, by devouring iron all the rust, or iron oxide ore, and, by devouring other kinds of matter,

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numerous other familiar substances. The compound, carbon dioxide, possesses little or no such life, and is well known to be as certain as water to drown out the life of an animal or fire that is completely immersed in it.

The purpose for which an ordinary fire is built is to produce a more desirable thing than carbon dioxide, namely, heat, which is described by one of the most eminent scientists of history as a "mode of motion". Can a person of "horse sense", without more evidence than the mere reputation, for science, of the writer who tells us of energy "stored-up" or "sleeping" or "locked up" in coal, believe for a moment that the heat of the fire comes from the carbon, and that the oxygen may be ignored? Can it be believed that such writer is not giving us "twaddle"?

"SOLIDIFIED SUNSHINE" is the title of a chapter in a recent and most interesting book from which one of the above quotations was taken. The modest and straightforward character of the book as a whole will banish any suspicion that this title was chosen because

> "When fiction rises pleasing to the eye Men will believe"

Sir Ray Lankester says (Second Series, 1912) that "science takes no heed of empty assertions unaccompanied by evidence which can be weighed and measured." Might he not have added "or common sense" to "science", or, at least, the common sense that is so fortunate as to be supplemented by sufficient education to enjoy scientific literature? But his remark, as made, implies that if the Master of Science, and Ph. D., who gave us "Solidified Sunshine", had obtained that idealism from a friend, he would have asked the friend, in substance: "How did you find out that sunshine, which includes heat, has taken a solidified, rather than a gaseous form, notwithstanding the familiar fact that the application of heat commonly tends to the production of the more tenuous form of matter?" A Master of Science will not be belittled by crediting his reader with enough mentality to recognize such "empty assertions", and to take no

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heed of them unless the evidence is found in literature more complimentary to the reader.

The literature above quoted has been written for the general reader. One of the books expressly says so, on its title page. If the general reader is to be fed upon imagination, why not give him something like this? —

Oxygen is the most abundant terrestrial substance known. It is also the most important to our lives, if it is logical to compare the importance of essentials. Its importance is certainly the most obvious. That it is the breath of life is known to everyone whose education has progressed as far as the word oxygen. It supplies the warmth and movement of our bodies. It heats the fire that cooks a meal, warms a dwelling or actuates a boiler. The progress and noise of a railroad train are but other modes of a motion of molecule, atom, electron or something still nearer the infinitesimal, that, shortly before, was going on with inconceivable speed, but silently, invisibly, impalpably, in the oxygen of the air about our heads.

In the animal processes carbon is the chief discard or waste. Oxygen is inhaled, picks up the carbon, and goes out with it. Then, with its load, the oxygen is wafted by atmospheric currents to a contact, at the appropriate time, with a trap which nature operates intermittently in green foliage. There the carbon is caught, and the oxygen, probably aided by an impetus from the sun, flies away to be again wafted by atmospheric currents to within the reach of the breathing of an animal that has eaten the carbon secreted by a leaf, when the cycle is repeated.

If the last two paragraphs are wild in imagining all the work to come from the oxygen, let them be modified so as to read part from the oxygen and part from the carbon. The writer does not believe, nor disbelieve, them. He simply feels that without evidence they come as near being good poetry as the rhetorical specimens above quoted, which, without evidence, have been thrown at him as facts.

Mr. G. K. Chesterton, who, whether or not thought of as "glib", is not likely to be accused of assumptions,

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either false or true, of the particular knowledge now commonly classified as "science", has stated the case in graphic form ("The Uses of Diversity," 1920), the asterisks, in the quotation, standing for further embellishments:

"There is a certain kind of modern book which * * * ought to be blown to pieces with the dynamite of some great satirist like Swift or Dickens * * *. The kind of book I mean is the pseudo-scientific book. And by this I do not mean that the man who writes it is a conscious quack or that he knows nothing; I mean that he proves nothing; he simply gives you all his cocksure * * * opinions and calls it science. Books are coming out with so-called scientific conclusions—books in which there is actually no scientific argument at all. * * * I should like some evidence."

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THE MUSEUM, THE ORIGINAL EXPONENT OF VISUAL EDUCATION*

FRANK C. BAKER, CURATOR, MUSEUM OF NATURAL HISTORY, UNIVERSITY OF ILLINOIS

We hear a great deal in these days about the value of visual education, and a society has been organized for the promotion of this method of teaching. This is indeed one of natures most effective methods of teaching her children the laws of the universe. It is said that we acquire much more information through the eye than through any other sense organ of the body. One often hears the expression "seein is believin," which expresses this truth in a homely way.

The museums of science and art have been for many years pioneers in the field of visual education, bringing to the public, more or less imperfectly in the earlier years, the facts of Science and the beauties of Art. The museum is often called the "peoples university," and it is quite true that the great majority of the population of our large cities acquire their only knowledge of the great world about them by visits to the museums, art galleries, and zoological gardens, where the fowls of the air, the beasts of the field, and the fishes of the sea, past and present, are gathered together in such an assemblage as Noah never dreamed of in his day and generation.

The value of the museum as an efficient aid in educational work is fully realized by but few educators. Even in many of the large cities there is little real co-operation between the local museum and the educational system, and this is by no means entirely the fault of the museum administrators. Visual education seems to center about pictures, lantern slides, and moving pictures, and the aid that may be rendered by the museum exhibits is, in the main, unthought of. Perhaps many of our museums are to be held responsible for this condition, their exhibits being so often entirely useless to the teacher because of faulty installation, of value to the systematic student,

* Contribution from Museum of Natural History, University of Illinois, No. 25.

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but valueless to the general teacher. The cooperative association of school and museum in New York, Chicago, Milwaukee, and some other cities, augers well for the future of the museum in finding its true place in the educational system of the present age.

In a recent article on the "Contribution of Museums to Public School Education," Mr. Peter A. Mortenson, Superintendent of Public Schools of Chicago, says: "The value of museum material as a factor in reinforcing school instruction has, no doubt, been recognized generally enough, but the difficulty lying in the way of its wider utilization has been the failure to find the museum material so organized that it would appeal to the dynamic interests of the children and at the same time portray the life that it was collected to represent." The larger museums, and even some of the smaller museums presided over by far-sighted curators, are removing this unfavorable criticism, and are preparing some of their exhibits to meet the requirements of the teacher of the grade schools.

That the museum is also of value in reinforcing instruction in the universities and other higher institutions of learning seems equally certain, supplementing by the exhibits the material used in the classroom and laboratory, the larger value being in the coördination of all the material which may have been seen in the classroom only as isolated parts of the whole subject. This value of museum material has been recognized for many years, and almost every college and university has its museum, even though it be a small one. Of late years some of the universities have drifted away from the use of the museum; hence the unsatisfactory condition of much of the material in many university collections and the general poor opinion of most of such collections among museum men. I wish to indicate, briefly, some of the ways in which the museum may be useful in supplementing the general courses given in a university.

The modern teaching of geography consists not so much of political boundary lines, as of peoples, industries, natural resources, and physical features. And here

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the museum can be of the greatest help in visualizing the text books. The cultures of peoples, how they utilize their natural resources and acquire material not found in their own country; the physical character of the country which has governed the development of the people, mountains, streams, valleys, deserts—all of these and more may be visualized in such a manner that the student easily grasps the significance of the facts of climate, topography, or geographic position, which have been potent in shaping the destiny of a group of peoples. The industries of certain countries may be shown, such as the common articles upon which we depend for our daily comfort—cotton and its derivitives—iron and steel—pearl and ivory buttons—coal—aluminum—and many others. Exhibits showing the processes of manufacture from the collecting of the raw material to the selling of the finished product, with all of the by-products indicated, are of potent value to the teacher of geography.

And in the natural sciences—geology, zoology, botany—the museum is indispensable because it visualizes the courses given in the different branches. The student pursuing a course in systematic zoology may study the synoptic collection, arranged so that the major groups are exhibited to show their development from simple to complex organisms, their relation to each other and to the past history of the earth, the extinct groups being shown with the recent groups. Such an exhibit links together all life, showing it to be interrelated on every hand.

The student of geology may crystallize his course in historical geology or palaeontology by consulting the exhibits of fossils, in which he may follow the changes of life from its first definite appearance in the early Cambrian seas to the latest prehistoric period. Here can be shown, as nowhere else, the dying out of one type of life and the advent, almost instantaneously as it seems, of another. Such examples as the dying out of the Ammonites in the Cretaceous, the rise and fall of the huge saurians in Mesozoic times, and the advent of the mammals in Cenozoic times indicate the usefulness of such exhibits. The subject of coal can also be made more understandable

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by an exhibit of the peculiar flora of the Carboniferous. The evolution or descent of an animal and its modification during descent can be shown most effectively by groups arranged with speciments or restorations, supplemented by illustrations, so that the student grasps almost instinctively the significance of the subject. Such lines of descent as the horse, sloth, elephant, and armadillo can be shown very effectively.

Physiography naturally lends itself to the museum treatment and all phases of earth processes may be illustrated most effectively. The work of ice, snow, water, the sea, vulcanism, erosion, these and other subjects may be made clear by the use of properly constructed models of effective sizes.

The modern group idea has revolutionized museum exhibits. By this medium we are able to visualize the whole realm of nature, history, and art. No longer must animals be seen only on shelves arranged in rows, like canned goods in a grocery; they may now be seen in their natural environment, in occupations such as they perform when unmollested by their arch-enemy, Man, the elaborateness and breadth of vision being limited only by the pocket book of the museum. In one museum may be seen the bird life of an island in the distant Pacific; in another, one may hunt the mountain sheep or the grizzly bear in the great mountains of the west; or visit a bird rookey in Florida or the islands of the West Indies. The fast disappearing native races of this and other continents may return and perform their ancient tribal ceremonies in the groups of the museum, which often appear so lifelike that one almost expects the wax effigy to breathe or to throw an upraised spear or stone through the glass of the case.

These groups need not be large or expensive. One of the most effective habitat groups in the museum of the University of Illinois is in a case 5 x 6 x 2 feet, in which is shown an old decaying log with its characteristic animal life in the midst of a local environment, a small patch of almost virgin woodland near the university. An enlarged photographic background, tinted, makes the old log appear to be in the woods, while spring flowers, birds,

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toads, and butterflies add to the naturalness of the exhibit. This group, including case and all accessories, cost but $400.00.

The modern study of natural history, now called ecology, may be aided very materially by these museum groups which visualize the life of different kinds of animal habitats, the natural homes of different species. Thus we may see the polar bear and musk ox of the Arctic, the deer and elk of temperate climes, and the gaudy birds of the tropics, all examples of the effect of climate on animal life. Pond life may be distinguished from river life, prairie life from forest life; all these may be shown in a museum group, surpassed only by the living animal in its real home. Often, two or more habitats may be shown in the same group for comparison, as a swampy quiet pond behind a beach barrier, the animals of the quiet pond being contrasted strongly with the animals of the rougher water habitat of an exposed lake shore.

In the teaching of economic entomology, the museum is again a valuable aid. In small groups, insects injurious to certain plants may be shown in their natural habitat on the plant as they would be seen when at work doing the injury, and the transformations may be shown so that the farmer or student may recognize the stage when the insect is most injurious. Such subjects as corn insects, grain insects, insects of the apple, pear, grape, garden insects, and many others may be shown as when living. These exhibits are far superior to the ancient custom of pinning the specimens in a glass covered tray, for the psychology of the group idea makes the insects seem more real.

And in botany, exhibits are possible that will be an aid in the teaching of some branch of the subject. Forestry, extinct plants, evolution and descent of certain types, these and other subjects may be treated in museum exhibits.

These examples might be amplified indefinitely, but enough have been given to show that the museum is a potent agency in modern education, a fact that is, perhaps, not fully realized by educators in general. The museum

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is too often thought of as a storeroom or mausoleum in which musty specimens are stored away to be pored over by spectacled savants who live in a world by themselves. It is sadly true that this conception is not without foundation, for there are many museums in universities, colleges, normal schools, and academies, which are this and nothing else. But the modern museum is a vastly different thing, filled with objects potentially arranged, awaiting use by all progressive teachers.

In closing may I use the words of one of England's greatest museum men, Sir William H. Flower, who says "It is not the objects placed in a museum that constitute its value, so much as the method in which they are displayed and the use made of them for the purpose of instruction".

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PAPERS ON BIOLOGY AND AGRICULTURE

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NOTES ON HAWAIIAN BOTANY WITH SPECIAL REFERENCE TO THE FUNGI

F. L. Stevens, University of Illinois

Hawaiian botany as well as zoology is of especial interest for several reasons. The extreme isolation of the islands, which lie some 700 miles from any considerable islands and nearly 2,000 miles from continental land, renders the question of the origin of the flora an interesting and important problem. Some botanists see in the plant distribution evidence of previous land connection, of land bridges whereby the ancestors of the present flora and fauna arrived, while others explain the present condition as due to the wind and water currents, even going so far as to distinguish separate waves of migration correlated with the geologic record of America, the submergence of Panama, and the consequent changes in ocean currents. The islands are entirely volcanic; Kauai, the northernmost, is doubtless the oldest; Hawaii, the southernmost, doubtless the youngest. Only coral on lava or lava itself may be trod upon. All of the islands have been repeatedly subject to lava overflows, Kauai long ago, Hawaii recently, perhaps today. These overflows have naturally profoundly influenced vegetation. In Kauai all has been quiet for ages, and immense canyons have been cut in the once hot lava. On Hawaii many lava flows during the last century and countless ones earlier have solidified into stationary stone rivers, often 30 to 60 miles long by several miles wide. These flows of all ages on Hawaii and their eroded counterparts on Kauai give most fascinating fields for ecological study. The character of erosion has produced wonderful canyons, cliffs and gorges, and miles of knife-edge ridges with abrupt changes in elevation and sudden transitions in rainfall. The top of Mt. Waialeale, Kauai, is the wettest place in the world, having a precipitation of 549 inches in 1920; other sections, Uuu Kea, had only 7.9 inches in the same year. These conditions also afford wonderful ecological opportunities. Sharp localization of flora is found on the two sides of a mountain or the

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opposite sides of a valley or on the lava flow of 1841 or of 1881 as it stretches through both wet and dry regions.

The flora of the island is highly endemic. Hillebrand states that excluding the species introduced by man there are 860 species, of which 653 or 76% are endemic with 40 endemic or peculiar genera, figures which are approximately true in the light of present knowledge. Many wonderful and interesting forms occur, e. g. the Silver sword and Gunnera.

It is, however, the fungi in which I am particularly interested. Less than 130 species, aside from those of economic crops, had been identified as occurring in the Hawaiian Islands prior to my collections of the summer of 1921, and very few of these had been recorded by publication. My own collections number something over 1200, and represent trips into all types of floras. Examination of some of these has been completed, and the results are being published by the Bishop Museum; others are being studied.

The genus Meliola and its near relatives are represented by 34 species on 58 hosts (4 on 4 hosts were previously known). Porto Rico gave 103. The ratio to available host species in Hawaii is .034 as against .046 in Porto Rico, a very significant difference showing the Meliolas to be approximately 50% more abundant in Porto Rico than in Insular Hawaii. The Meliolas are strictly limited to the ancient flora of the island and show decided evidence of western origin, being much more closely related to the Polynesian flora than to that of South America. This is particularly emphasized by the genus Meliolna, typically Phillipine.

Transition genera between families are also of especial interest. Thus the genera Meliola, Amazonia, Actinodothis present a series connecting the Microthyriacease with the Dothideales, and I believe that there is evidence from those studies that the present group of Dothideales is of polyphyletic origin. An interesting case of evolution occurs on Perrottetia in that there are both a well defined Amazonia and an Actinodothis on this host, clearly related as is shown by the hyphopodia and spores but now well differentiated into two genera; an evolution

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that evidently occurred from an ancestral form while on this host.

The rusts now number 38 on 44 hosts; fourteen are additions to the Hawaiian flora. In Hawaii there are 38 rusts on 999 potential hosts. In Porto Rico there are 175 rusts on 2250 potential hosts. In Indiana there are 172 rusts on 2339 potential hosts. The rust ratio of Hawaii thus is .038 as against .077 for Porto Rico and .073 for Indiana. The close agreement between the ratios of Indiana and Porto Rico is striking, while the low ratio of Hawaii shows rusts there to be approximately half as common as in Porto Rico. The absence of aecial forms is also striking; only one, an imported form, was found. As to their continental relationship, it appears that six came from America, one only from the West, and three others may have come from either east or west. Contrary then to the Meliolas the rusts appear to have been dominated by the east. Most of the rusts are clearly imported and of very recent existence upon the islands.

The six rusts on endemic hosts, too, are of very unusual character, consisting of isolated sori and not a general leaf infection such as is usual with other rusts. This condition suggests to me the possibility that these rusts are all as yet ill-adapted to their hosts. All of the evidence appears to show the rust flora to be recent as compared with the Meliola flora.

The Trichopeltaceae are particularly interesting morphologically, presenting a type of thallus unique in the fungi and in general resembling that of the liverworts. My collections in this group are larger than ever before made and result in several new genera and some modifications in classifications previously used. The genera Trichopeltis, Trichothallus, Enthallopycnidium and Anomothallus are of especial interest.

Microthyriella hibisci is of interest as throwing light on the possible relationship of the apple fly speck fungus.

Hexagonella is a remarkable form with solitary naked asci in a thallus of the type of the Hemisphaeriales.

The Dothideales, which are very numerous in Porto Rico, are very few in number. The genus Phyllachora so common here and in most places is represented by only

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two species, one possibly an import. The few Dothids that were collected are noteworthy. Yoshingiella shows a remarkable evolution on the tree fern Cibotium, it having evidently developed from a common ancestor while on this host into three distinct forms.

Pauahia, a genus which I have named in honor of the Princes Bernice Pauahia who did so much for science in the Pacific, is a very interesting transition form midway between the superficial radiate Microthyriaceae and the subcuicular non-radiate Dothids.

The smuts are conspicuous by their absence, only one really native one having been found and its birth place questionable, though smuts elsewhere are so common.

I have not time to discuss other groups, much though I would like to do so. It is evident, I think, that the questions in phylogemy and geographic distribution that arise in the Pacific are of keen interest, and that more complete knowledge of the insular fungus floras and of those of the east and west lands is needed.

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THE PRESENT STATUS OF PALEOBOTANY IN ILLINOIS

A. C. Noé, University of Chicago

The first Survey of Illinois contains in Volume 2 (1866) and Volume 4 (1870) numerous descriptions of fossil plants by Lesquereux. The Swiss naturalist, who had arrived in the United States as a companion of Louis Agassiz, was destined to become the father of paleobotany in this country, while Sir William Dawson had inaugurated the same science in Canada. Lesquereux's domicile was in Cincinnati, and he acted as a consulting paleobotanist for the newly created state surveys, as well as for the United States Geological Survey. His interests were broad, but the majority of his publications deal with the Paleozoic floras, foremost among which is the *Coal Flora of the Carboniferous Formation in Pennsylvania and throughout the United States.* In Atlas, Volume 1, (1879); Volume 2, (1880); and Volume 3, (1884) many specimens from Illinois are described and pictured.

Lesquereux apparently did not visit many localities, but had specimens sent to him. While this method saved much time, and accounts for the large amount of Lesquereux's publishing, it had obviously two drawbacks—the exact geologic horizon of the plant deposit was rarely determined with accuracy, and only specimens which looked good to the average collector were sent. Lesquereux did not have at his command the rich paleobotanic literature which the great French, English, and German paleobotanists produced in the last quarter of the nineteenth century, and in which the coal floras of western Europe were described. Therefore a rather complete revision of Lesquereux's determinations seems to be highly desirable before the study of American fossil floras can proceed much further. It is urgently to be hoped that a catalogue of the Paleozoic floras of North America may soon follow Knowlton's catalogue of the Mesozoic and Cenozoic plants of North America.

In the years 1906, 1907, and 1908, a new period of Paleozoic plant studies in Illinois was inaugurated.

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David White, now chief geologist of the United States Geological Survey, was invited by the chief of the State Geological Survey of Illinois, Frank DeWolf, to renew in cooperation with the State Survey the study of the fossil plants of the Illinois coal fields. During those years, Dr. White visited the plant deposits of the western and southern coal outcrops, and mining districts of Illinois. His observations are given in Bulletins 4, 8, and 14 of the Illinois State Survey. Dr. White had a great advantage over Lesquereux. He visited the localities himself, equipped with excellent geological experience, and he had at his headquarters in Washington one of the most complete collections of Paleozoic plants and paleobotanic literature at his command. Dr. White restricted himself in these publications to a preliminary report, and his larger treatment of Illinois coal plants is still to be hoped for.

The author has found the support of the State Geological Survey very helpful in making collections and observations throughout the coal seams of the state, in order to assist by the contribution of paleobotanic facts in the determining and revision of the correlation of Illinois coal seams.

During the summer, 1921, a number of localities in the following counties were visited: Jackson, Union, Williamson, Johnson, Pope, Saline, Harding, in southern Illinois; and Will, Grundy, LaSalle, Bureau, in northern Illinois. In the early spring of 1922 collections were made in McDonough, and outcrops visited in Rock Island, Knox, and Scott. The work is to be continued during the summer of 1922, and arrangements with the Geological Survey of Kentucky promise to give an opportunity for obtaining valuable information in that state, which may throw light upon certain paleobotanic problems of Illinois.

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NOTES ON ILLINOIS MUSHROOMS

W. B. McDougall, University of Illinois

CREPIDOTUS CINNABARINUS

This pretty little species has a bright scarlet or cinnabar-red, nearly sessile, cap which is usually only from ½ to 2 cm. broad. The gills are rather broad, not close together, cinnabar-red in color and brighter red or scarlet on the edge. The stem when present at all is very short, only 1 or 2 mm. long, and lateral. The plant grows on decaying logs in woods but seems to be very rare. It was first collected near Ann Arbor, Michigan, by an instructor in the University of Michigan, and sent to Peck about 1895. Peck (4) described it and named it, and it was not heard of again until it was rediscovered at Ann Arbor by Professor Kauffman some twenty years later. Kauffman's collection was made in November and the cold weather delayed the ripening of the spores to such an extent that he was unable to obtain a spore print. He found, however, that under the microscope the spores showed a slight tinge of red, and for this reason he expressed a doubt as to whether the plant really is a crepidotus or whether it should be placed in the genus Claudopus which is a pink spored genus. (2).

On June 7, 1919, I was fortunate enough to find a nice collection of this species in a woods near Urbana, Illinois. The specimens obtained were in very good condition and I succeeded in making satisfactory spore prints. Under the microscope the spores do have a pinkish tinge as Kauffman found, but in mass they are distinctly pale ochre or almost clay color. This proves that Peck was right, as likewise was Kauffman, in placing the species in the genus Crepidotus.

PLEUROTUS SUBPALMATUS (FIGS. 1 AND 2)

Kauffman's (2) description of this fungus is as follows:

"Pileus 3-5 cm, broad, fleshy, convex-plane, obtuse, the cuticle gelatinous, coarsely reticulated and separable,

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brick-red to flesh color, glabrous. Flesh rufescent, thick except at margin. Gills adnate, moderately broad, subventricose close, thin, a few forked at times or interspaces venose, becoming salmon color. Stem coriaceous-fleshy, confluent with pileus, 2-3 cm. long, 5-6 mm. thick, equal, somewhat eccentric, curved, fibrillose, fibrous-stuffed, reddish within and without. Spores globose, echinulate, whitish, flesh color in mass. On prostrate maple trunk, cut timber, etc. August-September. Rare."

This rare and interesting plant has been reported from Michigan, Ohio, Kansas and Minnesota. The specimen shown in figures 1 and 2 was collected in the University Woods near Urbana, Illinois, in September, 1921, and is, I believe, the first collection reported from Illinois. The plant was flesh colored throughout and agreed closely with Kauffman's description.

This species is not closely related to other species of Pleurotus. It differs from all of them in having echinulate spores and a gelatinous reticulated cuticle on the surface of the pileus. Moreover, Pleurotus is a white spored genus and our plant has flesh-colored spores, but, of course, that is true also of Pleurotus sapidus. Spore color does not seem to be always a dependable generic or even specific character. The genus Lepiota, for instance, is another white spored genus which has members that are not always white spored. The spores of L. naucina are sometimes white and sometimes flesh-color, while L. Morgani, which is usually classified with the Lepiotas, though perhaps it ought not to be, has green spores which become ochre color after exposure to light but which are never white. The other characters mentioned, however, do seem to separate Pleurotus subpalmatus from the other species of the genus, and Kauffman suggests that it is closely related to Heliomyces and perhaps should be placed in that genus.

SECOTIUM AGARICOIDES. (FIG. 3)

I have collected Secotium agaricoides several times in Champaign and Vermilion Counties, Illinois, and I have no doubt that many others have collected it in various

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parts of the state for it is not a rare plant. So far as I know, however, no report of its occurrence in the state of Illinois has ever been published, and it is such a unique and interesting species that the mere fact that it occurs in the state is worth reporting.

The fruit body looks like a puffball and is usually from ½ in. to 2 in. in diameter. It varies from spherical to top shaped and is whitish or gray in color. It has a short stem which continues clear through the plant as a columella. It grows in pastures and other grassy places and may be looked for throughout the summer from May to October, though it is most likely to be found in August and September. It appears to be widely distributed, collections having been made on all continents with the possible exception of South America. There seems to be no report as to its edibility though I have no doubt that it is perfectly wholesome at any stage before the spores begin to ripen.

This plant has usually been classified along with the puffballs, but Conard (1) has shown that its relationships are rather with the Agaricaceae. Its early developmental stages are similar to those of various members of the genus Psaliota which have been studied, and the mature fruit body is simply an Agaric that has failed to expand. Conard suggests that Secotium agaricoides should be classified in the Agaricaceae close to the genus Psaliota.

AMANITOPSIS ADNATA VAR. ALBA.

Late in September, 1921, Mr. Harold V. Scott of Monmouth, Illinois, sent me some specimens of Amanitopsis that differed in certain respects from any I had seen before. The cap was 4 to 6 cm. broad, white, smooth, but often with patches of the universal veil clinging to it, and had an even margin. The flesh was fairly thick and firm. The gills were adnate and rather close. The stem was from 5 to 6 cm. long, about 1 cm. thick and nearly smooth, but somewhat fibrilose below. The volva was very conspicuous and similar to that of Amanita verna. There was no sign of an inner veil so that there

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seemed to be no question as to the genus to which it belonged. However, it must be admitted that we know so little about the natural relationships of the mushrooms that we do not know how dependable certain characters, such as the presence or absence of an annulus, are and there is a question in my mind as to whether this plant may be an exannulate form of Amanita verna. I was influenced to think of this by the fact that Mr. Scott wrote that this plant grew in very sandy soil in oak woods along with Amanita verna. However, on our present basis of classification, this plant seems to belong unquestionably to the genus Amanitopsis.

The only species of Amanitopsis that I know of with adnate gills is A. adnata Smith. Our plant agrees with this species in many respects but differs from it in certain particulars. The cap of A. adnata is pale yellow and the volva is more lax and not so conspicuous as in our plant. Furthermore, the spores of our plant are narrower than those of A. adnata. The measurements given by Moffatt (3) for the spores of A. adnata are 10 by 8 microns while those in our plant measure 8 to 12 by 2 to 5 microns. In order to have a designation for the plant I am tentatively calling it Amanitopsis adnata var. alba.

PHALLUS IMPUDICUS. (FIG. 4)

Phallus (or Ithyphallus) impudicus, the common stinkhorn fungus, usually grows about 12 cm. tall, has a stalk about 2 cm. in diameter and a volva about 4 cm. in diameter. Early in July, 1921, after a series of rainy days there came several warm, clear days. During this time a large number of fruit bodies of Phallus impudicus appeared on a lawn in Urbana, Illinois, and these showed a greater variation in size than any I had seen before. The largest fully expanded fruit body was 15 cm. tall by 2½ cm. in diameter of its stalk, and its volva was 4 cm. in diameter, while the smallest specimen was 7½ cm. tall, its stalk 1 cm. in diameter and its volva 2 cm. in diameter. The eggs likewise varied greatly in size, the largest measuring 4½ by 6½ cm. and the smallest

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3 by 3½ cm. The explanation of this great variation in size is undoubtedly that the fruit bodies started developing during the rainy weather, and that with the coming of the clear days transpiration of water became more rapid than absorption and many of the fruits were unable to develop to normal size.

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NEW SPECIES OF FUNGI FROM ILLINOIS

H. W. Anderson, University of Illinois

In spite of the fact that Illinois in the past has been the collecting ground for a number of our most noted mycologists such as Seymour, Earle, Burrill, Waite and Clinton, there are still numerous species of undescribed fungi to be found parasitizing its rich flora. Illinois is on the border line between the hardwood forests of the east and the prairies of the west. To the north are the sand dunes of the lake and swamps of the Kankakee. To the south are the unglaciated hills. To the west we have large areas of river bottom with bluffs and ravines, while in the center is a great level prairie region. Through the central part of the state from north to south runs the broad right of way of the Illinois Central, and along this are many almost undisturbed areas where collecting is especially profitable. The cream has been skimmed from many choice collecting grounds by the industrious older mycologists, but there is little doubt that a systematic search in almost any locality would reveal many new species. As an example of this, I may sight a recent collection of an entirely new rust on *Laportea canadensis* (*Urticastrum divaricatum* Ktze) in a woods near Urbana which has been the favorite collecting ground of Burrill and his students for years. This rust (*Cerotelium dicentrae* Mains & And.) is of especial interest because it served to connect up the Aecidium on Dutchmans Breeches (*Aecidium Dicentrae*), a connection which has been puzzling the students of the rusts for many years. In this same woods two of the new species to be described were also found.

The five new species here described represent only a small part of a collection of "unknowns" which have been filed away for future work. The material can be examined only at odd times and it has been my desire to avoid making new species if possible. The recently organized plant disease survey of the state is responsible in part for the presentation of these new species since it was felt that all available material should be placed

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Fig. 1. Pleurotus subpalmatus. Dorsal surface.

Fig. 2. Pleurotus subpalmatus. Ventral surface.

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Fig. 3. Secotium agaricoides.

Fig. 4. Phallus impudicus.

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at their disposal at the earliest possible date. It is hoped that opportunity will be offered in the near future to prepare for publication a larger number of new species.

Septoria Collinsiae n. sp. Spots numerous, large 2-10 mm., single or confluent, often involving entire leaf, grayish white, suborbicular. Pycnidia strictly epiphyllous, acicular, straight or slightly curved 1-3 septate 2.5-3x25-50 microns. Mostly 3x30-40 microns.

The spore measurements agree closely with those of *S. Scrophulariae* Pk. but the character of the spots and the distribution and number of the pycnidia is quite different in the two species. *S. Scrophulariae* is a very common parasite on species of Scrophularia in this locality.

On *Collinsia verna* Nutt. Brownfield Woods near Urbana, Illinois, May 18, 1919, May 10, 1920, April 25, 1921.

Type No. 4723, Herbarium Illinois Plant Disease Survey.

This leaf spot was so abundant that it caused the death of large patches of the host. It is strange that this serious disease has escaped the attention of collectors in this region.

Septoria septentrionalis n. sp. Spots numerous, small, indefinite, often confluent, brown, later with white indefinite centers. Pycnidia epiphyllous rarely amphigenous, few, scattered, brown, thin walled, 60-80 microns. Pycnospores very short for this genus, narrowly fusoid, straight or slightly curved, ends blunt, 1 septate or continuous 2.5-3.5x15-25 microns. Differing from *S. ranunculorum* Lev. *S. Ficariae* Desm. *S. polaris* Karst., *S. Ranunculi* Westv. *S. ficarioides* Peck, in the small size of spores and character of leaf spots. Not to be confused with *Ascochyta infuscans* E. and E. on *Ranunculus abortivus* which has thicker and somewhat shorter spores. It approaches *S. polaris* more closely than any other species described on Rununculaceous posts.

On lower leaves of *Ranunculus septentrionalis* Poir, near Urbana, Illinois, (Brownfield woods) April 21, 1921.

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Type specimen No. 4725, Herbarium Illinois Plant Disease Survey. This leaf spot was rather rare in the locality where it was collected although the host plant was fairly abundant. A critical study of the Septorias on Ranunculus is needed.

Gloeosporium Impatientis n. sp. Spots numerous, large (3-15 mm.) circular or more often irregular, rusty brown with red to purple border on upper surface, grayish beneath; acervuli numerous, small, pulvinate, or elongate and large along prominent veins, pink to white, hypophyllous; spores oblong-ovate, 3.5-5x15-23 microns, contents granular, basidia very short or absent.

On *Impatiens biflora.* Urbana, Illinois (Brownfield Woods). August 19, 1921.

Type specimen No. 4722, Illinois Plant Disease Survey Herbarium.

This spot has appeared annually during the past three years in the regions where it was first collected. It seems to cause considerable injury to the host. It is also common about Crawfordsville, Indiana, where it was collected by H. B. Dorner, September 23, 1907, and was later observed by the writer in a number of localities in Montgomery County, Indiana. The collection by H. B. Dorner is labelled "*Impatiens aurea*", (*I. pallida Nutt.*), but it is probable that this is a mistake since *I. biflora* is by far the more common species about Crawfordsville. The collection by Dorner is No. 4721 of the Illinois Plant Disease Survey Herbarium.

Phyllosticta Rafinesquii n. sp. Spots few, mostly on lower leaves, 2-5 mm., circular, light brown with small definite gray center. Pycnidia, few, scattered on spots on living leaves, but more numerous on dead leaves, Epiphyllous, black (brown under microscope with cells of neck much darker), flask shaped, 120-175 microns with neck 50-60 microns. Pycnospores oblong, 1-3 guttulate, 3-4 x 10-14 microns. Differs from *Phyllosticta Violae* Desm. in larger size of spores and pycnidia and in the character of the spots.

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On *Viola Rafinesquii* Green, Anna, Illinois, April 23, 1921.

Type specimen No. 4724, Herbarium Illinois Plant Disease Survey.

Although the host plant occurs over large areas in the region where this disease was collected, the spots are rare and easily overlooked. Where they occur the dead or dying leaves on the lower part of the stem yield abundant pycnidia.

Ascochyta Rhodotypi n. sp. Spots definite, large, angular and irregular, white with narrow dark red edge; sometimes involving large areas on the leaf when the red borders are much broader and more irregular. Pycnidia scattered, few, amphigenous 140-180 microns with distinct papillate ostioles. Cells of pycnidial wall large, light brown. Pycnospores hyaline, uniseptate, oblong, ends rounded, slightly constricted at septa, straight, 3-4 x 11-15 microns.

On leaves of *Rhodotypos kerrioides* University Campus, Urbana, Illinois, July 15, 1919 and September 10, 1919.

Type specimen No. 4726, Illinois Plant Disease Survey Herbarium.

Few diseased leaves were found on any bush, but the disease appears each year on the same branches. Three clumps of bushes have been watched and the disease has appeared in a mild form on these three successive summers.

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NOTES ON NEW DISEASES OF ECONOMIC CROPS IN ILLINOIS. 1919-1921

H. W. Anderson, University of Illinois

The presence of new diseases among our economic crops is a matter of grave concern to the agricultural interests of the state. Having found these new diseases, the question at once arises as to their importance and what measures should be taken to control them. We are far too careless today in the matter of protecting our crops by careful inspection and quarantine, and as a result of this carelessness, due in a large measure to lack of foresight of the growers themselves, there have been introduced into the state many destructive diseases which add to the already heavy toll taken by crop pests. The lack of interest due to ignorance concerning the nature of fungus and bacterial parasites makes the task of the plant pathologist all the harder when an effort is made to restrict these diseases. When a new insect is discovered making inroads, there is no lack of publicity to excite and alarm the grower. But the publicity given to fungus diseases is so pitifully inadequate that no extensive program of eradication or control can be successfully carried out.

No systematic survey has been made of economic crops to determine what new diseases occur in the state. The few new diseases here recorded have been more or less accidental discoveries. No doubt some of these have been present for a number of years and there is little question but that many have been overlooked. It is hoped that the newly organized Plant Disease Survey of the state may bring to light many more such observations as are embodied in this publication. The recent accidental discovery of flag smut of wheat in Madison and St. Clair counties is not described in these pages since adequate publicity has already been given this disease. The facts concerning the discovery of this disease, however, are of interest because of the value which a very minor survey operation may have. In the spring of 1919 while examining the wheat fields near Granite

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City, Illinois, for a new disease called "take-all" or "foot rot", one of the scouts of the U. S. Dept. of Agriculture found a few stalks infested with a smut, which until then, was not known to occur in the United States. An intensive survey during the next two years revealed the presence of this disease in a number of fields in Madison and St. Clair counties, and every effort is now being made to restrict it to these counties and finally entirely eradicate it from the western hemisphere. Had this disease been unobserved for a few more years, there is little doubt but that it would have become established in an area of our wheat belt that would have rendered its eradication as hopeless as the other smuts of wheat.

In some cases new diseases may cause unnecessary alarm. It is important, therefore, to present as accurate an account as possible of the disease and estimate its importance according to the experiences of growers where the disease is prevalent. That it may behave differently, i. e., be more serious or of less importance, in its new home due to changed environments is a fact recognized by plant pathologists.

The diseases given below are of no great economic importance with the exception of the leaf scorch of strawberry which may become in a few years one of our most serious strawberry diseases. To date we have had few diseases of this delicious and valuable fruit which seriously interfered with its development. In fact, the diseases are of such minor importance that spraying strawberries is not practiced in any section of the state. Judging by the effects of the leaf scorch on our variety plantation at the University it is evident that it will be necessary to hold the disease in check on certain of the most susceptible varieties or give up hope of growing these varieties.

APPLE

Rough Bark (*Phomopsis Mali Rob.*)

A twig of apple showing a roughened condition of the bark was received from Ralph Wemper, Assumption, Christian County, in March, 1921. On the rough bark

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many pycnidia were observed which upon examination proved to be these of *Phomopsis mali.* A fresh lot of specimens were later received. These showed the same rough character of the bark, but the type of injury on these larger branches resembled more nearly the rough bands produced by the blotch fungus (*Phyllosticta solitaria*). Scale was also evident on two branches, and since scale produces a rough bark similar to that of both blotch and the true rough bark disease it is apparent that some doubt might arise as to the true cause of this condition.

Phompsis mali has twice been obtained on apple twigs kept in moist chambers and a number of times on blotched limbs so that it seems to be a fairly common fungus.

An examination of Mr. Wemper's tree showed the presence of numerous active blotch cankers on the young twigs so that there seems little doubt but that the rough bark condition was produced by *Phyllosticta solitaria* and not by *Phomopsis mali.* If *Phomophsis mali* were an active parasite under Illinois conditions it is apparent that it would have caused serious trouble on account of its general distribution. The mere presence of this fungus on rough bark is not sufficient evidence, therefore, that the diseased condition is due to this organism.

CHINA ASTER

Leaf spot (*Septorio callistephi* Gloyer). Destructive blighting of the lower leaves of seedling plants of the china aster (*Callistephus chinensis* Nees) was observed in the University floricultural greenhouses in the spring of 1921. Many of the plants were so stunted as to be worthless. After the plants were set in the field the disease gradually disappeared. This was aided no doubt by the dry hot weather of June and July. Collections were made of the leaf spot and a microscopic examination showed that the disease was due to a Septoria.

Gloyer (Phytopath. **11**: 50, 51, 1921) describes a new species of *Septoria* on China aster from New York which

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he names *Septoria callistephi.* He writes in regard to the disease:

"Certain commercial plantings of the china aster, *Callistephus chinensis,* in New York have been severely attacked by *Septoria callistephi* n. sp. The disease was first observed in 1915 and again in 1919 and 1920. In unsprayed plantings, all of the plants of some of the suspected colored varieties were killed. The white varieties appear less attacked, and Semple's White Branching, while not entirely immune, is resistant. The pycnidia are found in the scurf covering the seed and the disease is spread in the seed bed. The lower leaves are first diseased but later the upper leaves and floral parts are attacked. The tawny colored spots may be isolated but, finally, unite and kill the entire leaf. The plant becomes dwarfed, the size of the flower reduced, and the time of blooming is delayed. The exact control measures have not been fully worked out, although it appears to be amendable to treatment by seed disinfection and spraying with Bordeaux mixture."

Prof. Gloyer has kindly examined the material collected in Illinois and states that it is identical with his. He further states that a bulletin on this disease is in process of preparation and will soon be forthcoming (Geneva, New York Experiment Station.)

The importance of selecting seed from plants known to be free from the disease is emphasized by Gloyer's observations, and commercial growers should either produce their own seed in disease free beds or secure seed from sources where this disease does not occur.

SEDUM

Leaf spot of *Sedum spectabilis* (*Septoria Sedi* West). A bed of *Sedum spectabilis* in the University ground showed a disfiguring leaf spot in the fall of 1921. Upon examination this was found to be due to a Septoria. Three species of Septoria have been listed on *Sedum purpuream* (*S. Telephium*), *Septoria Sedi.* West., *S. Telephii* and *S. sedicola* Peck. Two of these, *S. Sedi* and *S. sedicola,* are reported from America. These two species cause spots identical in character and differ in such

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minor details that they may be regarded as synonymous. A *Septoria* has never been reported on *Sedum spectabilis* either in America or elsewhere. The spots on this host are very similar to those on *S. purpureum* and the fungus is probably identical with *Septoria Sedi* West.

Sedum spectabilis is supposedly of Japanese origin while *Sedum purpureum* was introduced from Europe. It would be of interest to attempt cross inoculation on these two hosts.

The spots while not numerous are large (5-10 mm.). Sunken, circular in outline, black above and dark grey below. The very numerous black pycnidia may be seen with the hand lens. They are somewhat more abundant on the upper surface, but are distinctly amphigenous. They measure 80-120 microns. The spores are 2 x 30-50 microns, but mostly between 35 and 45 microns. They are septate, mostly straight and needle shaped. The spores of *Septoria Sedi* on *Sedum purpureum* as represented by No. 3081 Fungi Columbiani range somewhat smaller, the most common lengths being 25-35 microns. The character of the spots, however, closely agrees with those in *Sedum spectabilis.*

It is suggested as a control measure that the plants be cut down as early in the autumn as possible and that the leaves be carefully raked from the beds. Both the plants and fallen leaves should be completely burned. I have found viable spores in the pycindia of the fallen leaves as late as April 1st of the year following infection.

SPINACH

Blight, yellows or **mosaic** (cause unknown). Spinach plants having symptoms of the well-known blight of the Virginia truck region were received in November, 1921, from Belleville, St. Clair County. Since spinach blight is not known to occur in this state, specimens were sent to Dr. J. A. McClintock, Georgia Experiment Station, who has had a wide experience with this disease in Virginia. He confirmed my diagnosis and stated that, so far as he knew, this was the first report of the occurrence of the disease west of Ohio.

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Spinach blight is a disease similar to many other mosaics and "yellows", in that it is caused by some virus in the juices of diseased plants which when transferred to healthy plants produces the disease just as though parasitic organisms were present. At one time it was thought to be a nutritional disease, but this has been disproved. Similar symptoms often appear, however, when there is a deficiency of certain essential elements such as potassium.

Symptoms. A typical blighted plant has mottled, malformed leaves. The leaves are curled and wrinkled, the plant is dwarfed and the general color is yellow in contrast to the dark green of the normal plant. The younger leaves near the center of the plant show the most marked symptoms. Unlike many other mosaic diseases, spinach blight results eventually in the death of the plant. The leaves finally turn yellow, become spotted with dead brown areas and the plant soon dies.

Aphids are the main and only important agents of transmission. The disease is probably not transmitted either through the root or by seed. The aphids which attack the spinach feed upon many other plants, and the disease virus not only lives in the insects when they are feeding on other plants, but is transmitted through several generations. For this reason when the disease is once established in a region it is extremely difficult to eradicate it. Attempts to control the disease by destroying the aphids have so far failed on account of the habits of the insects and their enormous breeding power.

The seriousness of this disease is indicated by the statement of Dr. McClintock that the *annual* loss to the truck growers of Virginia alone is between $200,000 and $400,000. Since there are large areas devoted to spinach growing in Illinois it is important that this disease be not allowed to become prevalent.

It is suggested that a survey be made of the truck regions of the state to determine the extent of the disease. If it is limited in its distribution to a few fields it may be possible to abandon the growth of spinach in the neighborhood of these fields until the disease had disappeared. If the disease is widely distributed the only re-

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course is to develop disease resistant strains. Fortunately the growers in Virginia have at present a strain of savoy spinach which is highly resistant under their conditions. This should be tried in Illinois, and if at all resistant should be exclusively grown in the regions where the disease occurs. A number of the growers should organize to grow and improve the seed of this strain and keep it pure.

BLACKBERRY

Powdery Mildew (*Sphaerotheca humuli* (D. C.) Burr.). On May 13, 1921, a number of mildewed wild blackberry bushes were found near Odin, Marion County, Illinois. Since no surface mildew had ever been observed on cultivated blackberry the specimens were carefully examined to determine the species. It was evident that they were *Rubus alligheniensis*. No perithecia of the mildew were found at this time.

An examination of the literature revealed the fact that no powdery mildew had ever been described on the common blackberry although reports of *Sphaerotheca humuli* on the dewberry and other species of Rubus are common. Burrill states that he collected a powdery mildew on *Rubus strigosus* (dewberry) at Champaign and that Earle had collected it on this host in Union County. They did not find perithecia.

It is probable that this mildew will never become a serious menace to blackberry production under Illinois conditions. The summer of 1921 was exceptionally favorable for powdery mildews.

OAK (QUERCUS.)

Strumella canker (*Strumella coryneoidea* Sacc. & Wint). This canker was found abundantly on oak at Tonti, Marion County, in 1919. It caused girdling and death of the twigs. It is not a very destructive disease so far as the oaks are concerned, but since it also attacks the chestnut and since this tree is grown extensively for commercial purposes in southern Illinois, the disease may assume considerable economic importance in the future.

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This canker is common in the northeastern states, and is reported as especially destructive in Pennsylvania where it occurs on the white, red, yellow and chestnut oak and on the American chestnut.

The canker caused by the fungus resembles that of the European apple-tree canker. They are oval to elliptical in outline with concentric folds about the slightly sunken central area. On the surface of the cankers are numerous small black pustules, the fruiting bodies of the fungus.

RASPBERRY

Dodder (*Cuscuta gronovii.* Willd.) Specimens of red raspberry canes encircled by dodder were received from S. I. Talbot of DeKalb. He wrote that this started on a single bush in 1920 and had spread to six or eight since. He stated that it was evidently sapping the life out of the plants. The species of dodder was kindly determined by Prof. T. S. Yuncker. Clinton reports dodder as occurring on raspberry in Connecticut. (Plant Dis. Bul. Suppl. 14:101, 1921.)

Since this species of Dodder is very common and occurs on a large number of hosts it may easily be introduced into berry patches. For this reason dodder growing on wild plants in the neighborhood of berry patches should be destroyed.

CALENDULA

(*Calendula officinale*)

Rust (*Puccinia recedens* Sydow). The calendula has become a popular annual flower for the home flower garden and is extensively grown in greenhouses for cut flowers during the winter. Therefore, any disease which threatens this plant is of considerable economic importance.

In the summer of 1920 a rust was observed on a number of these plants grown in a home garden at Urbana. Specimens were sent to Dr. H. S. Jackson of Purdue University who identified the rust as *Puccinia recedens* Sacc. He stated that it had never been reported on this

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host but had been collected by J. M. Bates in 1907 at Lincoln and St. Paul, Nebraska. Later it was learned that Dr. Lehenbauer had also collected it on a single plant in the University of Illinois Floricultural Greenhouse in 1919. The rust was again found in 1921 on calendulas grown in the same garden where it was observed in 1920.

It seems probable that this rust is seed borne. While it occurs on Senicio this host is not common in the region about Urbana and has never been observed to harbor a rust when observed. The fact that the disease was observed on a greenhouse plant also indicates seed as a source of infection. The soil used in the pots is not a likely source of infection. The rust also occurs on *Dimorphotheca cuniata,* a common ornamental plant, but this had not been grown in the region about Urbana for a number of years.

Seed sterilization is suggested as a remedy for this rust. To date it has not been general enough to warrant expensive control measures nor has the injury on individual plants been severe since the spots are few and scattered.

GOURD

Anthracnose (*Colletotrichum lagenarium* (Pass.) Ell. and Hals.). A variety of an edible gourd known as the Australian Bean has been grown in the University vegetable garden during the past two years. On account of the prolific production of fruit on this plant there has been some thought of recommending it as a desirable cucurbit for the garden. It is of interest, therefore, to know something concerning the diseases which attack it.

In the autumn of 1921 a number of fruits of this gourd were stored in one of the University buildings. When examined in October several were observed to be in a rotting condition and many more were covered with lesions of a disease which resembled watermelon anthracnose. Some of the spots were small and quite numerous while others were several inches across. In the cases where rotting had set in, the fungus had extended through the outer hard rind into the pulpy interior where it often

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produced a solid mat of mycelium with numerous sclerotial bodies. The spore masses on the exterior were light yellow or salmon colored, or in some cases where the surface was dry they had turned black, due to the presence of numerous dark cells (not setae).

An examination of the literature revealed the fact that *Collectotrichum lagenarium* (Pass) Ell. and Hals. (*Gloeosporium lagenarium* (Pass.) Sacc.) was originally described in this country as occurring on old gourds in the vicinity of Philadelphia in 1882.

This disease has always been regarded as one of the most destructive diseases of watermelons and is occasionally serious on canteloupes and cucumbers. Since gourds have not previously been grown in the region where this disease occurred so abundantly it is probable that it was transferred from one of the above hosts which were growing in the neighborhood of the gourds, or was in the soil in which the gourds were planted. Its virulence on this particular gourd variety is so marked that it will evidently play an important part in the future development of this vegetable.

STRAWBERRY

Leaf scorch (*Mollisia earliana* (E. & E.) Sacc. *Marssonia potentillae* (Desm.) Fish. *Marssonia potentillae* var *fragariae* Sacc.) This disease was first observed in the University variety plantings in 1921. An examination of many berry beds in the vicinity of Champaign and Urbana and in other sections of the state failed to reveal any of the disease. It seems evident, therefore, that it was introduced on the plants and has not become widely disseminated. The plants were received in 1917 from Kellogg's Nursery, Three Rivers, Michigan, where the disease is known to occur. It is quite probable that other introductions of the disease have occurred in other sections of the state since it is the practice of growers to obtain their plants from Michigan nurseries. The disease is more destructive than the ordinary leaf spot and efforts should be made to prevent its general spread. So far as is now known the most popular varieties of strawberries in Illinois, Dunlap and Burrill, are not very

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susceptible. This statement is based on the fact that these varieties have been growing in close proximity to the diseased varieties for several years and were received from Kellogg's Nursery along with the diseased varieties.

Bederana is by far the most susceptible variety. Other varieties showing the disease are Eresko, Sionilli, Kelloggs Prize, Kelloggs Big Late, Superb (everbearing), Glen Mary, Lady Corneille and Gibson.

Leaf scorch is common in Canada and has been reported from a number of eastern states. It is also known to occur in Louisiana, Indiana, and Michigan.

Symptoms. The spots are usually much more numerous than those of the common leaf spot, often giving a blotched purple appearance to the entire leaf. The individual spots are small, at first, (as compared with *Mycosphaerella fragariae* spots), usually two to five mm. in diameter, somewhat irregular and deep purple on the upper surface of the leaf. The centers of the spots appear slightly raised above the surface of the leaf and are black. The coal black, slightly wrinkled fruit bodies of the fungus may be seen with a hand lens. On the lower surface of the leaf the spots are much lighter in color and much less distinct. The spots are in evidence also on the petioles of the leaves and on the fruit stalks.

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THE ILLINOIS PLANT DISEASE SURVEY

LEO R. TEHON, STATE NATURAL HISTORY SURVEY

INTRODUCTION

Wherever agricultural pursuits are followed to an extent that is nationally important, plant diseases demand a large amount of attention because of their destructive character. The establishment in July, 1921, of a Plant Disease Survey in Illinois is a recognition of this fact.

It is the purpose of this paper to present to the Academy of Science an outline of the problems which lie within the province of the survey, and to summarize the results of the first season's work.

The Plant Disease Survey is one of the activities carried on by the State Natural History Survey in its program of study of the biological phenomena of Illinois. The purpose of the survey may be outlined as being concerned with three chief tasks:

1. To ascertain what diseases occur within the state of Illinois.
2. To study their distribution throughout the state.
3. To determine how much damage they do.

So broad a generalization as this enumeration indicates may best be defined within its limits through a more detailed examination of the lesser tasks involved in each of the above.

ASCERTAINING WHAT DISEASES OCCUR

Plant diseases may be classed, for our present purpose, as being either important, or unimportant, from an economic point of view. Whatever disease attacks a plant grown for its agricultural value whether or not it is, in itself, serious, must be considered as an economic disease, for it adds in some measure directly to the total crop loss of the state from plant diseases. It is essential, therefore, that all diseases of crop plants shall receive some attention. The amount of attention may, however, be distributed either in accordance with the value of the crop or the importance of the disease to the crop. One would expect to pay but little attention to the

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lettuce or radish bed in the city garden, while much effort would be expended justifiably upon the group of diseases attacking more important crops such as corn, cereals, and fruits.

Diseases unimportant economically need to receive a reasonable amount of study because their study may lead to the development of facts applicable in an important way to the understanding of those diseases which are economically important. Such study also serves directly in the advancement of purely scientific knowledge which is, of course, the basis of all of our practical applications. In this category will be included all diseases occurring on all plants whether weeds, herbs, shrubs or trees, not usually grown as crops.

The scope of the survey must lie largely, if not entirely, within that group of disease caused by microscopic fungi and organisms of an allied nature. This is especially true since diseases of this type of origin constitute by far the greater number and variety of affectations to be dealt with among plants, and because those morbid conditions due to the attack of predatory insects have long since been recognized as lying within the province of the entomologist.

THE STUDY OF DISEASE DISTRIBUTION

In its essential aspect, this phase of the survey work may be expressed briefly as determining in what localities diseases occur. In the practical application of control measures, as well as in the purely scientific consideration of plant diseases, a knowledge of geographic distribution is often of real value. In the application of control measures it may indicate to what extent the program is practical, or it may serve to determine the amount of territory to be included in the program. And in course of time it may serve to determine the degree of effectiveness which the control measure has attained. From a scientific view point, information of real value may be developed through the correlation of details of time, place and severity of infection with weather conditions, edaphic host relations, etc. The ultimate scientific use of these facts would be in the development of principles of an

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ecological character, of important conclusions of an epidemiological nature, and may even lead to the possibility of predicting with reasonable certainty whether or not epiphytotics of any disease should be expected in a given season.

It is probable that some distinction exists between what should be considered as "survey" and what "inspection". The work of a survey may be said to be of a more extensive nature, concerned with the whole aspect of a problem, rather than with any small part. For the present at least the Plant Disease Survey finds it impossible to consider plant diseases in any greater detail than as to how they affect whole counties. Counties are chosen as an arbitrary unit for lack of any sufficient ecological or agricultural stratification of the state.

DETERMINING DAMAGE DONE

This is probably the most difficult phase of the work which the Plant Disease Survey plans to undertake. Under any circumstances, estimates of damage are bound to be merely relative. In the case of grains, for example, while one may determine rather accurately the damage done to a given plant by such diseases as smut and scab where it is considered that the loss is limited largely to the affected grain, these diseases which are of a more generally parasitic nature such as the rusts present problems in estimation that are difficult in the extreme. Arbitrary scales for judging the percentage of infection on a given plant might serve admirably for this purpose were it not for the numerous complicating factors. In the case of rust, where the ultimate damage is apparent mostly in the shrivelled grains, there are other factors tending toward the weakening of the plant and the smallness of grains, such as early ripening in dry and hot weather, the presence of minor parasitic agents such as Helminthosporium, glume blight, etc.

It is, nevertheless, very necessary that some sort of estimate of damage be made because it will have a very real value in pointing out, if only in a relative way, the true importance of plant diseases in limiting crop production, and in indicating where there is need either of

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careful scientific consideration or the application of well-advised prevention or control programs.

Certain methods may be of use in this kind of determination. In the first place, there should be secured in large quantity data showing the percentage of infection upon individual plants. To this should be added data showing the percentage of diseased individuals in separate fields, and the percentage of diseased fields in a county. A correlation of this information, based upon expected yield, with the actual yield, will lead to relatively accurate determination of the damage done.

CORRELATED ACTIVITIES

While the importance of the Plant Disease Survey lies chiefly in its ability, through its attention to the distribution of disease and its other studies, to direct attention to those diseases which are of a particularly dangerous nature, so that proper control measures may be developed or applied at the proper time and in the proper places, according as the need may be, there are in addition a number of possibly less important but none the less vitally needed lines of endeavor which must of necessity fall within its scope. Several of these have been mentioned in previous paragraphs, but a grouping of them at this point will serve to emphasize them in their proper relation.

In bringing together observations concerning the origin of diseases and their relation to the weather, temperature, moisture, etc., there seems to be some justification in supposing that attempts, in a small way, may soon be made toward the forecasting of outbreaks of diseases, and that this may be increased as time goes on and data becomes more generally available. The coupling of this possibility with timely warnings concerning the preventive measures which may be advisably applied would render a service of real value from an economic stand point.

Since the survey is concerned with all parasitic diseases of plants, it becomes its duty to develop an herbarium containing specimens of all diseases occurring

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within the state, and from every county in which the disease occurs.

In connection with the study of diseases not having special economic importance, it becomes the duty of the survey to attend to the scientific study and description of all new diseases. It is also necessary to watch carefully the entire state for the presence of newly imported diseases, and have on hand information showing newly reported diseases in other places which might invade the state and cause additional crop losses.

SUMMARY OF THE FIRST SEASON'S WORK

Following the beginning of the work of the Plant Disease Survey early in July of 1921, the lines of work outlined above have been carried on to as large an extent as possible.

Attention has been given to as many crops as possible, and collections of specimens have been made, and estimates of damage arrived at, in co-operation with other agencies throughout the state.

While, at the time of the beginning of the work, the grains of the state were largely cut and harvested, it was possible to make a survey through several counties on the northern boundary of the state. The material gathered here was correlated with other information received from various sources from several parts of the state, and combined with the information on hand at the Department of Crop Production at the University of Illinois with the assistance of Mr. G. H. Dungan, to form an estimate of the damage to grains through the various parasitic diseases.

Fruit, vegetable and other crops were still available for a reasonable amount of attention following the establishment of the survey. As a consequence, a relatively larger amount of data was collected along this line than in the case of cereals. This data was combined with information on hand in the Horticultural Department of the University of Illinois, and the two sets combined in

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co-operation with Dr. H. W. Anderson are presented in summary below:

Summary of fruit, vegetable, and ornamental diseases for 1921.

FRUITS.

APPLE:

Bitter rot (Glomerella cingulata)—Local damage averaging 1% in orchards planted to late varieties in southern part of state.

Black rot (Physalospora cydoniae)—Distributed throughout the state. Loss approximately 2%, chiefly through rotting of wormy fruit.

Blister canker (Nummularia discreta) — Generally distributed throughout the state, but more severe in southern Ben Davis orchards.

Blotch (Phyllosticta solitaria)—Distribution general southward, present locally northward. Reduction in yield about 5%.

Brown rot (Sclerotinia cinerea)—Appeared generally throughout the state, chiefly on wormy fruit, causing only a trace of damage.

Blight (Bacillus amylovorus)—Attacks were chiefly local and more severe northward. Damage about 1%.

Cedar rust (Gymnosporangium juniperi-virginianae)—Present chiefly south and westward. Damage only a trace, due chiefly to leaf injury. Occurring especially on Benoni, York, and Wealthy.

European canker (Nectria galligena)—Not generally distributed. Only one case reported. Little if any damage.

Fruit spot (Phoma pomi)—Present in the state but not generally distributed. No damage.

Powdery mildew (Podosphaera leucotricha)—Widely distributed throughout the state, but important only in nurseries. Crop damage little if any.

Rough bark (Phomopsis mali)—Probably widely distributed though not commonly reported. No appreciable damage.

Scab (Venturia inaequalis)—The most important apple disease. Distribution general, with 95% of the orchards of the state infected. An estimated reduction in yield of from 10 to 15%.

Root rot (Xylaria sp.)—Present locally in extreme south, not an important disease.

Root rot (Armillaria mellea)—Rare in Illinois. No appreciable damage.

Jonathan spot—A very important disease on Jonathan apples. Distribution general.

Measles—First reported last season. Not now important.

Cracking (due to weather conditions)—Serious locally on Stayman's winesap.

PEAR:

Blight (Bacillus amylovorus)—Loss very slight. Present mostly as twig blight which was checked by hot weather of June and July.

Leaf spot (Fabraea maculata)—Very important disease. Present in epiphytotic form in Marion and Union counties. Especially severe on French seedling stock in nurseries.

Leaf spot (Mycosphaerella sentina)—No loss. Appeared late in the season.

PEACH:

Bacterial leaf spot (Bacterium pruni)—Distribution general. Some losses locally resulting from defoliation.

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Leaf curl (Exoascus deformans)—Distribution general. Damage slight if any.

Scab (Cladosporium carpophylum)—Abundant generally on twigs. Loss undeterminable.

PLUM:

Bacterial spot (Bacterium pruni)—Distribution general, but damage slight.

Pockets and *leaf curl* (Exoascus pruni and E. communis)—Local distribution, resulting in leaf curl and deformed twigs. Damage none.

Black knot (Plowrightia morbosa)—Distribution general. Loss undetermined.

CHERRY:

Leaf spot (Coccomyces hiemalis)—Distribution general. Damage undetermined.

GRAPE:

Black rot (Guignardia bidwelli)—Generally distributed. Found in 95% of vineyards of the state, causing loss of approximately 20% of the state's crop. The most serious grape disease.

Downey mildew (Plasmopara viticola)—Distribution general. Appearance late, with the wet weather of August and September. Damage slight, mostly leaf injury.

Powdery mildew (Uncinula necator)—Distribution general. Damage slight if any.

BLACKBERRY:

Anthracnose (Plectodiscella veneta)—Generally distributed. Loss 2 to 5% of the crop.

Crown gall (Bacterium tumefaciens)—Present throughout the state, injuring between 5 and 10% of the plants.

Yellows (Physiological)—Distribution general, more severe northward. Loss approximately 2% of the crop.

CURRANT:

Angular leaf spot—Distribution general, damage slight.

Anthracnose (Pseudopeziza ribis)—Distribution general, serious only locally, causing defoliation. Damage slight.

GOOSEBERRY:

Anthracnose (Pseudopeziza ribis)—Serious locally, though generally distributed. Causing defoliation. Damage slight.

STRAWBERRY:

(Physiological)—Present in Champaign and Marshal counties. Not important.

Leaf spot (Mycosphaerella fragareae)—Distribution general, but serious only locally. Total damage about 2%.

Leaf scorch (Mollisia earliana)—Present in Champaign county and serious on the Bederana variety.

The cold wave, occurring over the entire state about the middle of April, 1921, did a great deal of damage to the fruit crop of the state. As a result, estimates of damage which should be based upon yield could not, in

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many cases, be made because there was practically no crop on those plants.

DISEASES WORTHY OF NOTE IN 1921

It is worth while calling attention to certain diseases which, during the past season, were especially destructive either in state wide or in local epiphytotics.

At Libertyville, in Lake county, red raspberry plantings were suffering severely from an attack of physiological leaf curl. This disease is known commonly among growers as "yellows" and as "Marlboro disease". There is no known cause for the disease, and effective treatments are unknown. While this disease is not widely distributed through Illinois at present, wherever it has appeared it has been one of the most serious diseases of the raspberry. The losses from this disease in the severely infested raspberry plantings in Lake county has been estimated to be nearly 90% of the total crop.

Several patches of strawberries in Lake county were injured to the extent of a 50% crop loss through the attack of the strawberry leaf spot caused by *Mycosphaerella fragariae.*

The Physoderma disease of corn, while prevalent throughout the southern half of the state, was nowhere severe with the exception of an area around Eureka in Woodford county, where the disease was reported as doing considerable damage. Samples received and examined by us were so severally diseased that we feel justified in estimating a loss of at least 25% in this area. This is especially remarkable in view of its northness.

In all of the cabbage growing sections of the state, the disease known as cabbage yellows, caused by *Fusarium conglutinans,* was the cause of an important reduction in the yield of the cabbage crop. Damage was particularly heavy in the Peoria district, and in the small gardens of Champaign County.

In Coles county, black knot of plum, caused by *Plowrightia morbosa,* appeared in rather more than its usual destructive abundance. In the same county broom corn blight, caused by *Bacillus sorghi,* appeared to be damaging beyond use about 1% of the plants in the fields, but

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the damage from the two smuts of broom corn appeared much less than that due to the bacterial disease.

One bad outbreak of alfalfa leaf spot, caused by *Pseudopeziza medicaginis,* appeared in St. Clair county, and Jonathan spot on apples appeared to be a serious problem in Vermilion county, as was also tomato wilt caused by *Fusarium lycopersicae.*

NEW DISEASES

During the season of 1921 there came to our attention several diseases not hitherto reported in Illinois. Several of these diseases occurring on fruits, vegetables and ornamentals are described in a paper by Dr. H. W. Anderson and need not be discussed here.

Along the lake shore north of Lake Bluff in Lake county, several greens on an expensively built golf course were being very badly damaged through the attack of *Rhizoctonia solani.* Often the loss would be as much as $500 for a single green since great care was being exercised in caring for the course, and especially imported seed of the New Zealand fescue grass was being used for seedage. This troublesome disease has hitherto been reported only from the neighborhood of Washington, D. C., and it seems unlikely that in Illinois the disease will become of more than a local importance. The parasite causing the disease seems to be a normal inhabitant of forest soils, and is readily transplanted from woodlands to golf courses or grass plots in the neighborhood. The parasite seems to be spread from green to green on the golf course by the shoes of the players and caretakers, and its development and spread on the green itself furthered by the presence of abundant moisture. On greens not wholly level the course of the spread of infection corresponds strikingly with the course of water used for irrigation. Cool moist nights appear to favor the development of the fungus, and in the mornings it can usually be detected as a thin, cobwebby film of fungous hyphae running among the leaves of the grass. The collection of dew among its mycelial strands gives it the appearance of a fine cloud lying in the grass. The heat of the sun on a bright dry day seems sufficient to stop the advance of the fungus,

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and it does not apparently spread farther from the one spot, all further damage to a green resulting from the new infections.

A stalk rot of corn made its appearance in some of the fields of Monroe and Jackson counties. This stalk rot appears to be of bacterial origin, is not grossly similar to Stewart's disease, and has certain points of similarity with a disease described by Rosen as appearing in Arkansas.

SURVEY SERVICE

The Plant Disease Survey has assisted in the quarantine area in Madison County, where a program of control and eradication is being waged by the State of Illinois Department of Agriculture against the recently introduced flag smut of wheat caused by *Urocystis tricici.*

There is also available, through the efforts of the survey, a complete list by parasite, by host, and by locality of every disease so far known to exist within the state. A bibliography, comprising about 325 titles, indexes all publications concerning the presence of plant diseases in Illinois.

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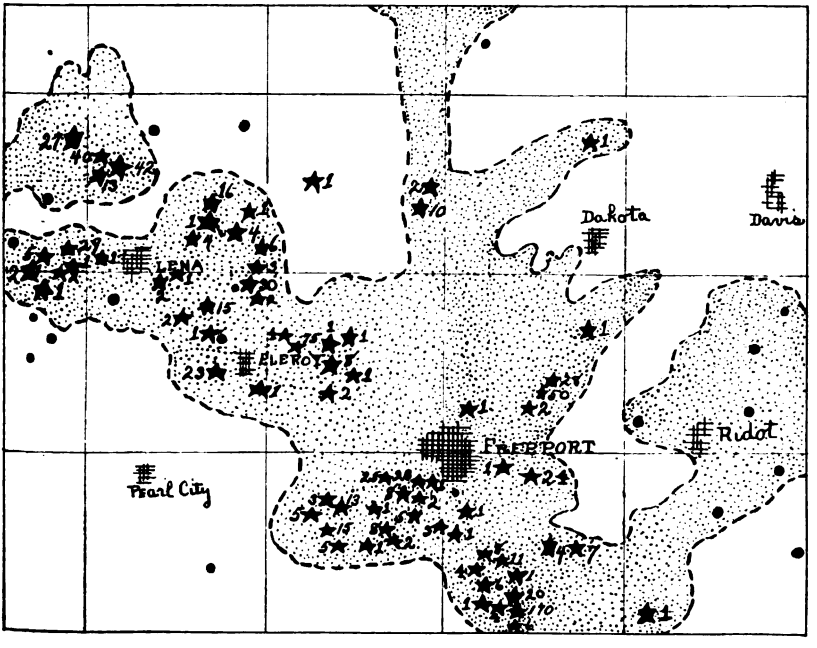
THE HABITAT OF NATURALIZED COMMON BARBERRY IN ILLINOIS

LEO R. TEHON, STATE NATURAL HISTORY SURVEY

An important problem in the prosecution of the country survey for common barberry in Illinois, as well as in twelve other states, has been to determine in what places one might expect to find barberry shrubs escaped from cultivation. That some index of locations favorable for the naturalization of the shrub would greatly expedite the survey can not be doubted.

The presence of the common barberry (*Berberis vulgaris* Linn.) in the United States, it is generally admitted, is due to its introduction from Europe. DeCandolle (1) points to its absence from the islands west of America and east of Asia, which might be supposed to serve as distributional bridges between the two continents, as a geographical indication of the agency of man in its intro-



Map 1. Stephenson County. Scale ¼" = 1 mile. * Location of escaped plantings. • Location of cultivated plantings. Figures indicate numbers of bushes.

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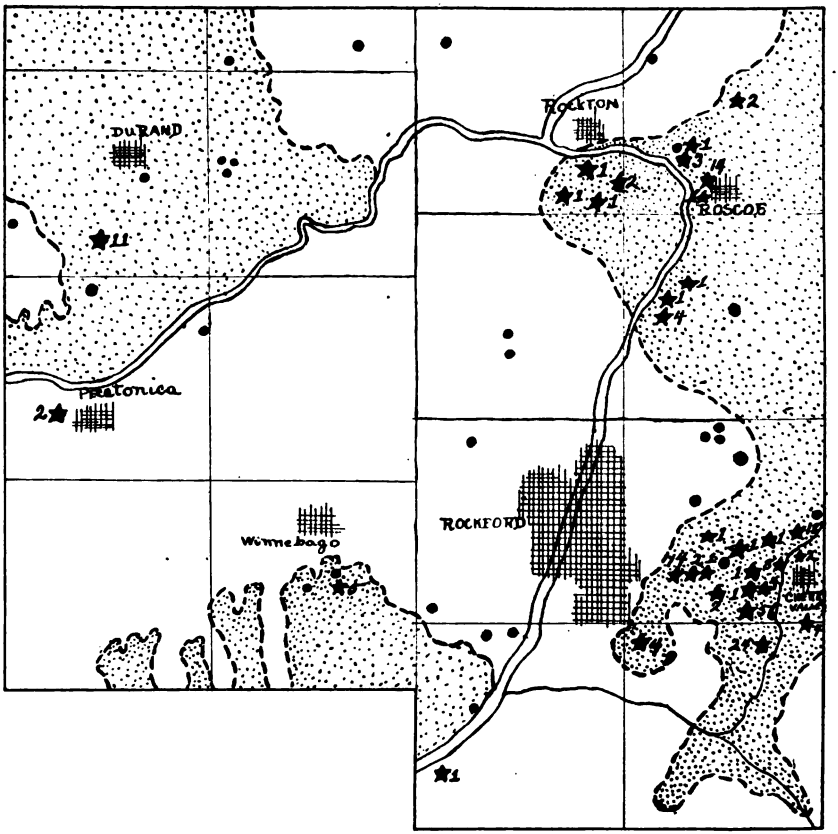
duction to America. Following its introduction, it has spread both as an ornamental shrub and in its naturalized condition throughout a large area in the cold-temperate belt of our continent.

The first point where the shrub was introduced into America was probably along the coast of New England where Sir Charles Lyell (2) speaks of it as having been introduced, supposedly as an ornamental shrub. Sir Charles Lyell also attributes its spread toward the interior, in a naturalized state, to the agency of animals which eat the berries. In our botanical manuals, it is probably first mentioned as having become naturalized by Bigelow (3) as early as 1813 near Boston.



Map 2. Winnebago County. Scale ¼″ = 1 mile. * Escaped plantings. • Cultivated plantings. Figures indicate numbers of bushes. Dotted areas—Primeval timber land.

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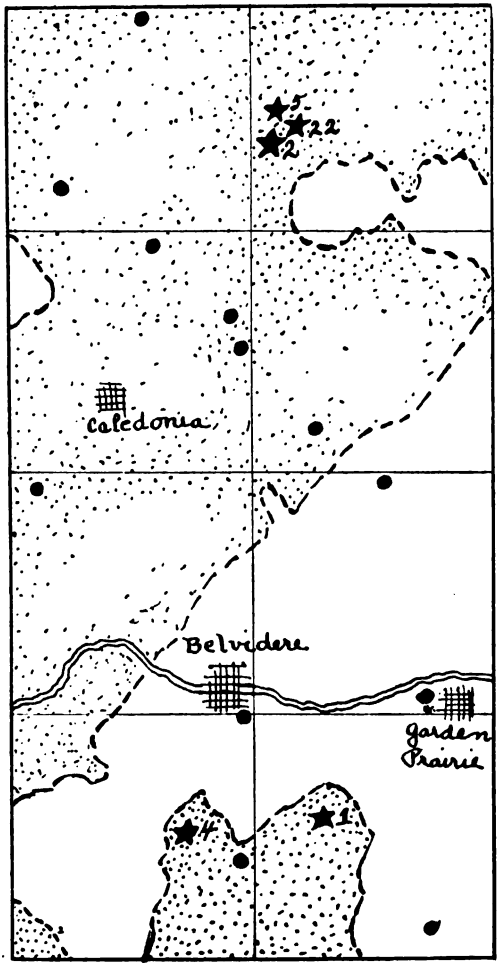
From its point of first introduction and naturalization, the shrub has spread westward across the continent, traversing in its role of decorative shrub, dye-producer, jelly-maker, and spreader of rust, the paths of migration in company with the hardy pioneers of our early history. In Illinois, its presence, both as old and large cultivated shrubs and hedges and in extensive naturalized plantings, still marks the pathway of the early settlers from east to west and indicates those places which our forefathers con-



Map 3. Boone County. Scale ¼″ = 1 mile. Markings same as Map 2.

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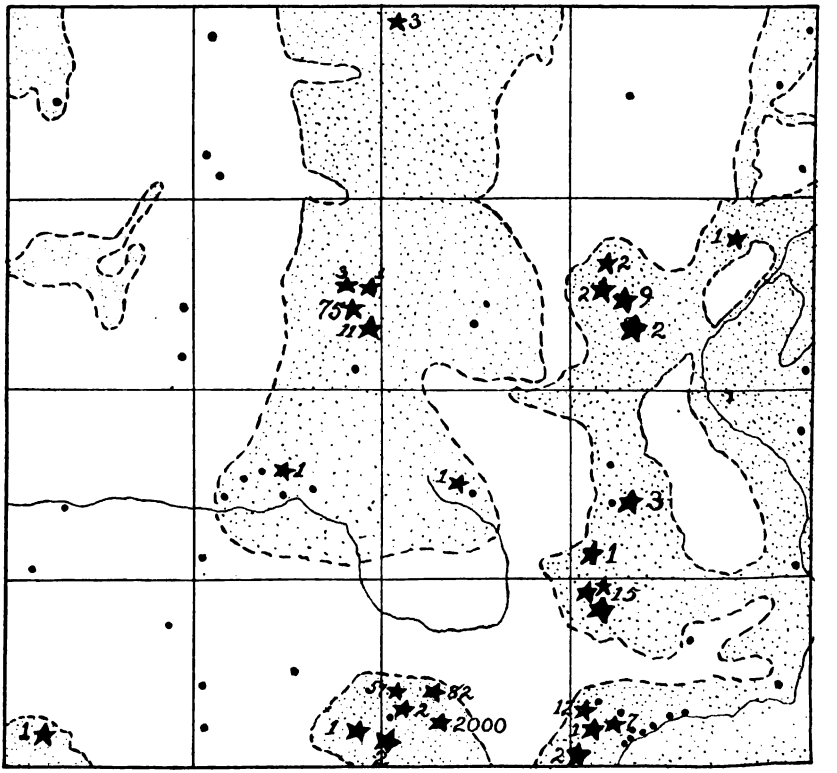
sidered most promising for settlement and home building. Always in those places where it has been long established, it has escaped from cultivation and spread itself throughout the countryside; sometimes in many plantings consisting of large numbers of well developed shrubs and multitudes of seedlings; and sometimes only in occasional adventitious plantings having a few scrawny weakling shrubs.

Such variation in numbers, both of escaped plantings and shrubs, together with a very apparent lack of uniformity regarding the chemical nature of the soils they inhabit, has led to a certain amount of speculation as to the ideal habitat for the barberry.

It is obvious that, since the barberry depends for the dispersal of its seeds upon the assistance of birds (4),



Map 4. McHenry County. Scale ¼″ = 1 mile. Markings same as Map 2.

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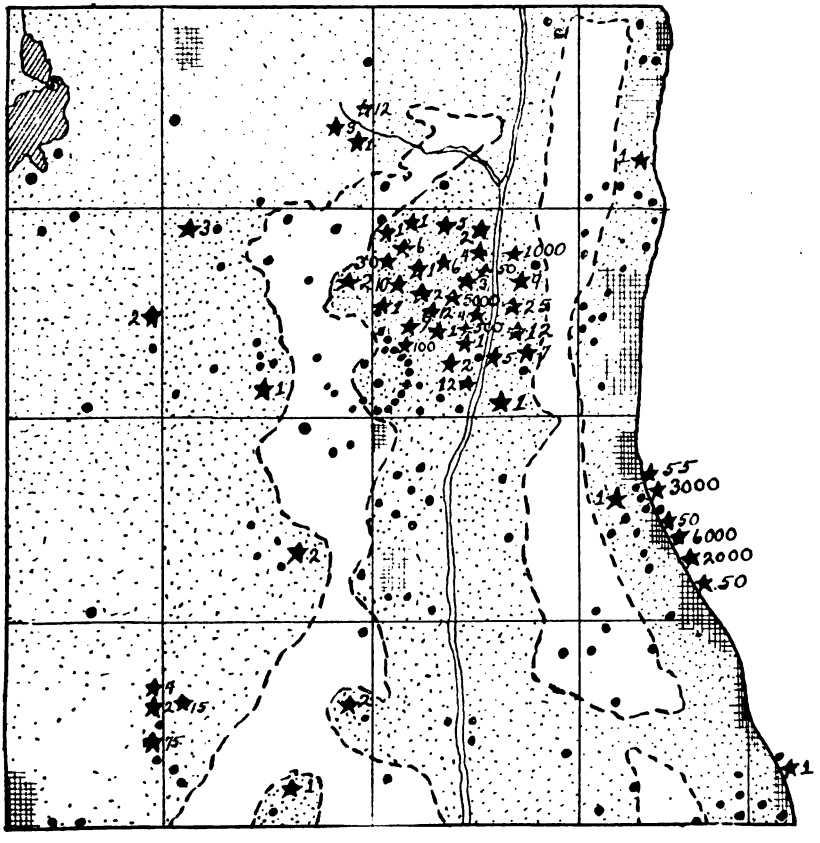
(5), (6) and other animals (7), (2), the location of escaped plantings must be determined, in some degree, by the presence of floral or topographic situations likely to be visited by the birds and animals after feeding. This fact is illustrated by the relation of naturalized and cultivated plantings as shown in maps 1-8. Relative distances are certain to be important. An area in Lake county drawn on map 9 (Township 45 North, Range 11 East of Third Principal Meridian) shows the profusion of naturalized plantings to be expected where favorable bird habitats abound in close proximity to cultivated shrubs. Whether or not the seeds so distributed shall spring up into tall-growing, vigorous shrubs or, having sprouted, shall eventually succumb to environmental in-



Map 5. Lake County. Scale ¼″ = 1 mile. Markings same as Map 2.

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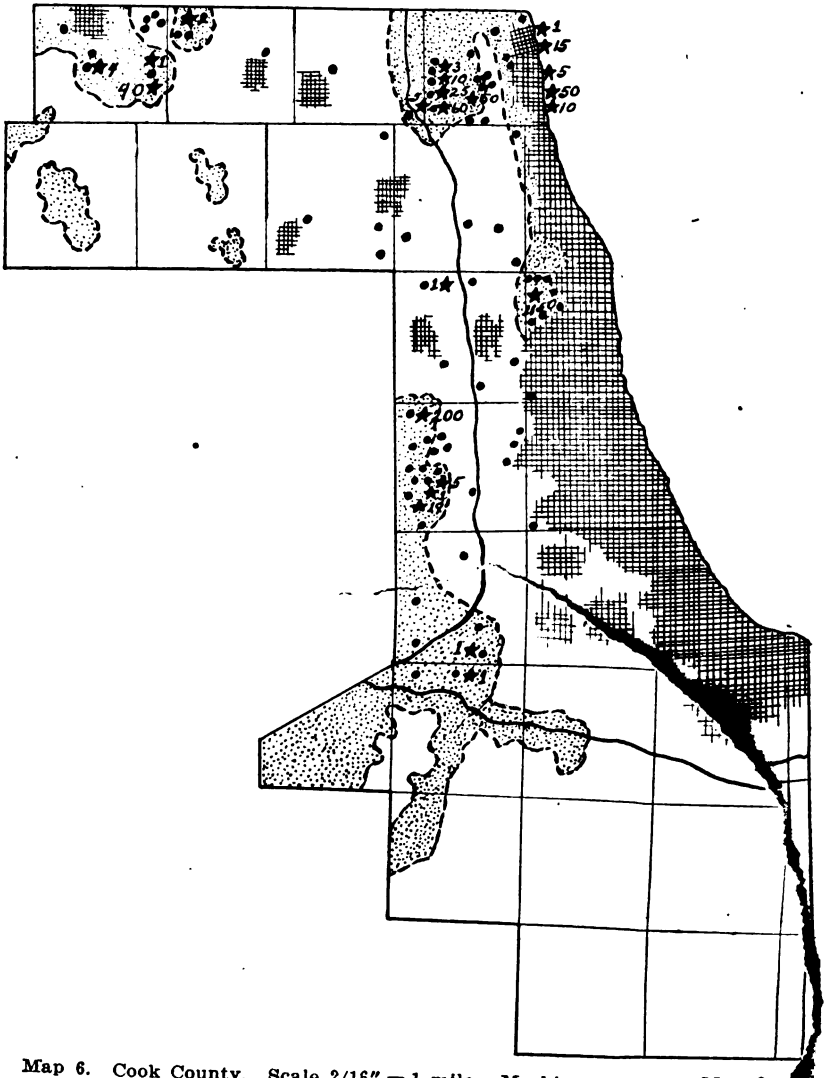
fluences will, on the other hand, be determined by factors of an origin and significance different from those controlling only the dissemination of the seeds.

In the first years of the barberry survey, it was supposed that the most favorable locality for the development of wild plantings was in regions characterized by calcareous soils. This opinion seemed supported, in our



Map 6. Cook County. Scale 2/16″ = 1 mile. Markings same as Map 2.

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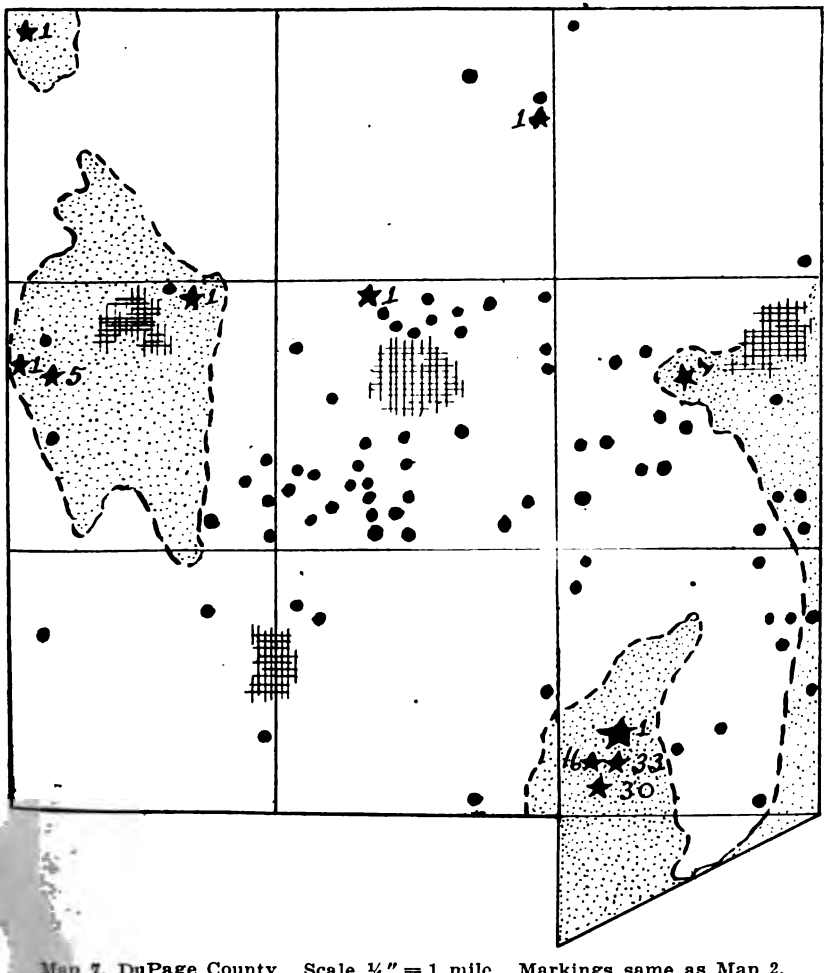
limited experience, by the frequent reports of plantings occurring in or near limestone quarries. As time has progressed, reports of barberries comfortably naturalized in many other situations, such as, for example, among the dunes of Michigan and the shales in Illinois, have indicated that some other explanation for habitat must be sought. The wide range of habitat is indicated by Kern (8) for Pennsylvania, as in "residual soils, whether formed from sandstone or shale, limestone, igneous and metamorphic rocks. Glacial soil seems to be equally favorable. * * * In thickets, along streams, along



Map 7. DuPage County. Scale ¼" = 1 mile. Markings same as Map 2.

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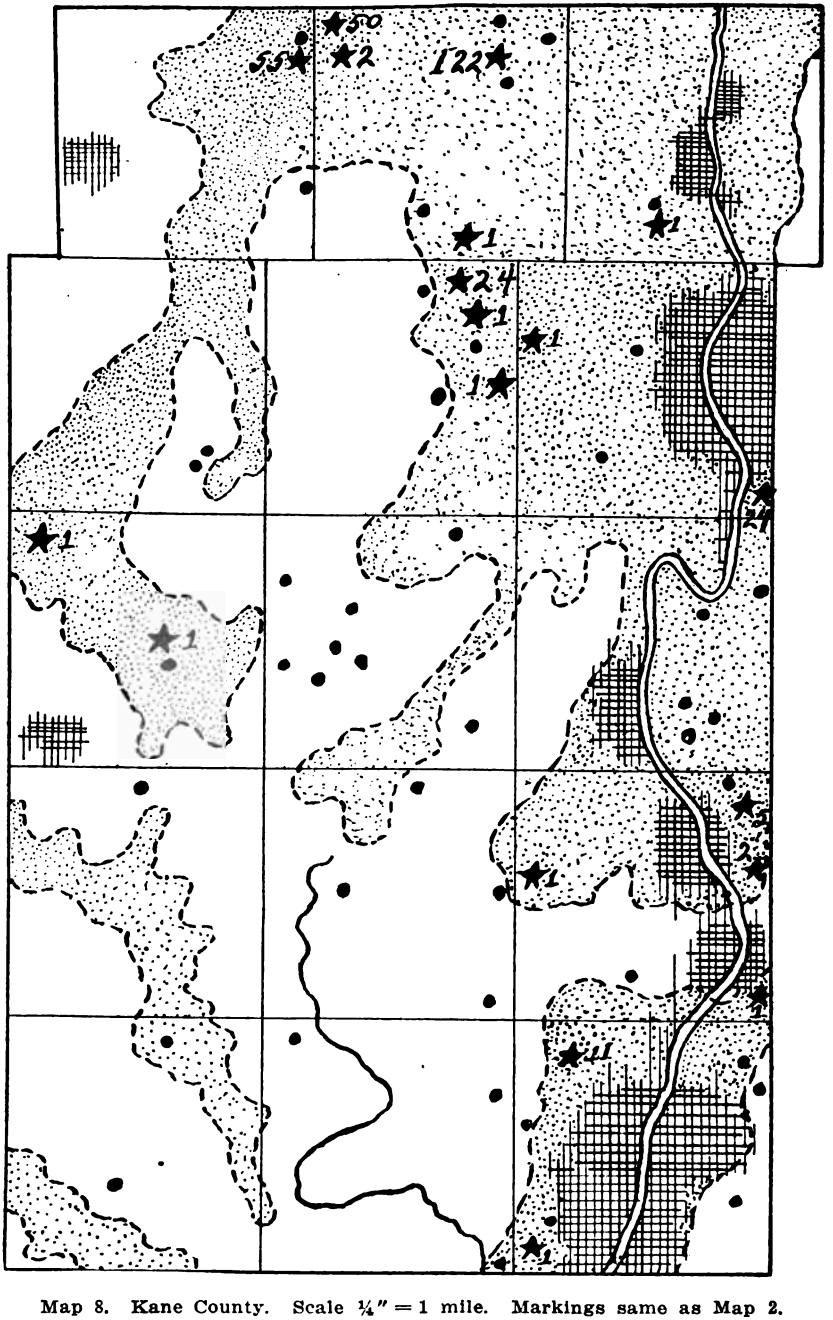

Map 8. Kane County. Scale ¼″ = 1 mile. Markings same as Map 2.

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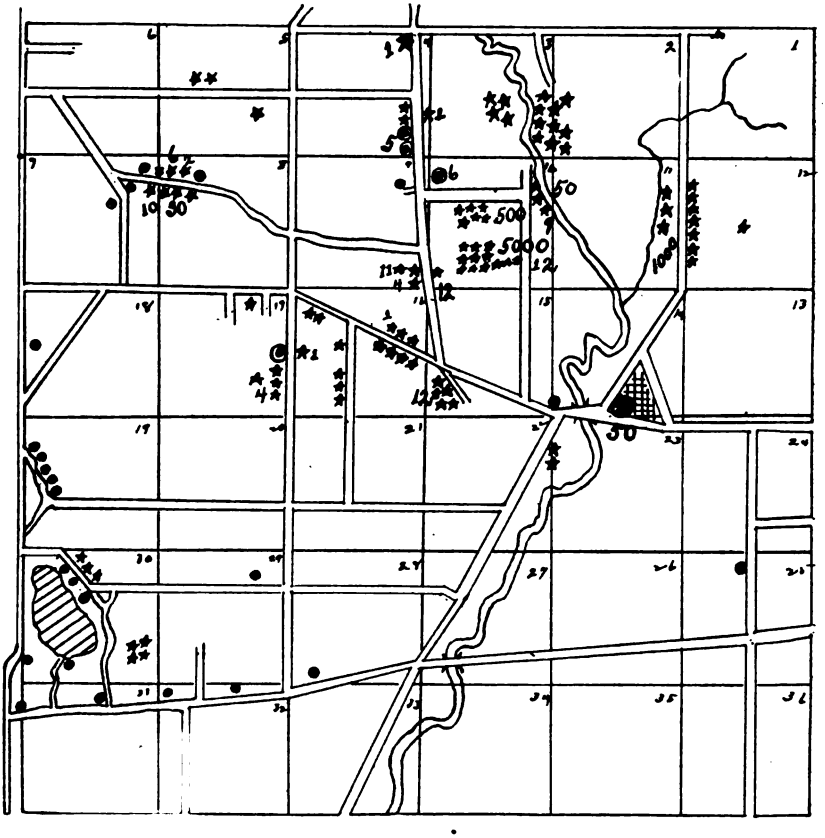
roadsides, in open pastures or half-wooded hillsides, this plant seems to be at home." There would be no difficulty in enumerating locations in Illinois which would duplicate each item of Kern's heterogeneous list. Yet, in Illinois, there seems to be a consistent relation which may be pointed out as existing between naturalized plantings and the locations they occupy.

This relation is not to be seen in any consideration, individually, of our many escaped plantings; but it is apparent in a complete grouping of them all in relation to the dominant features of the habitat in which they are found to occur.



Map 9. Territory surrounding Gurnee, Lake County.

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As a preliminary basis and to provide as substantiating evidence the fact that reasonably large numbers of observations are available, the following tables are included.

TABLE 1.

Total barberry plantings found and removed in eight counties:

Counties Alphabetically	Cities and Towns	Number of Properties in Country Having Escapes	Total	Both, on which bushes were Found	Removed
Boone	48	1	20	68	68
Cook	1371	27	107	1478	1401
DuPage	336	12	82	418	345
Kane	490	7	33	523	418
Lake	2298	65	176	2474	2360
McHenry	209	26	74	283	264
Stephenson	119	93	110	229	229
Winnebago	631	64	75	706	706
Total	5502	295	677	6179	5791

TABLE 2.

Total barberry plantings found and removed in entire state:

Survey	Cities and Towns	Number of Properties in Country Having Escapes	Total	Both, on which bushes were Found	Removed
Original	7724	346	794	8518	5523
Resurvey	....	....	....	....	....
Removals	....	....	....	....	2250
Total	7724	346	794	8518	7773

TABLE 3.

Total barberry shrubs found and removed in eight counties:

Counties Alphabetically	Cities and Towns	Number of Bushes in Country Escaped	Total	Both cities and country Found	Removed	Sprouts Found on Resurvey
Boone	2426	1	119	2545	2545	4
Cook	10935	1610	5058	15993	14200	113
DuPage	7232	84	3305	10537	7058	201
Kane	9053	241	1119	10172	9314	222
Lake	10784	18914	20706	31490	28379	462
McHenry	3707	2480	3313	7020	4098	250
Stephenson	1426	860	1320	2746	2746	705
Winnebago	5825	281	686	6511	6511	320
Total	51388	24471	35626	87014	74851	2277

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TABLE 4.

Total barberry shrubs found and removed in entire state:

Survey	Cities and Towns	Number of Bushes in Country Escaped	Country Total	Both cities and country Found	Both cities and country Removed	Sprouts Found on Resurvey
Original	92500	25635	42289	134789	81841	.....
Resurvey	.....	.....	.....	.....	.....	.....
Removals	.....	.....	.....	.....	33056	2336
Total	92500	25635	42289	134789	114897	2336

As previously mentioned, the first supposition that the common barberry might find especially favorable conditions for wild growth in calcareous situations has not been substantiated by later experience. This is a condition which should probably be expected since Schimper (9. p. 100) remarks especially concerning the variation of the flora found on calcareous soils, in that in places plants may be found to be calciphilous, elsewhere silicifilous, and elsewhere apparently indifferent. He also notes (9. p. 100) that one species may be calciphilous in one area, calciphobous in another, and indifferent in yet a third. It may be doubted whether, in such cases, chemical characters of the soil are of so much importance as are associational or edaphic factors.

In the eight counties of Illinois surveyed thus far for barberry, there is apparent a correlation between the location of escaped shrubs and the area once occupied by our primeval forests (10). Maps 1-8, in which escaped plantings are indicated, illustrate this fact and it may also be seen that in a majority of cases the plantings are located near the edge of the forested areas. It may be thought that this fact is due to the majority of settlements being located first upon the edges of timbered areas; but in locations toward the interior of timber areas where naturalized shrubs have been found, it is constantly observed that they are on the edges of the forest and present only when clearings are relatively large. Only two plantings, each of a single shrub, are at present known to occur in dense forest. Neither of these is far removed from the forest's edge, and each apparently is surrounded by secondary growth whose origin is more recent than that of the barberry.

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This is a condition which, in its total aspect, approximates rather closely the habitat of the barberry in the Carpathian region, where, according to Pax (11), "am Waldrande und an licteren Stellen des Hochwaldes erscheint ein charakteristisches Buschwerk aus *Berberis vulgaris*" and other shrubs. A similar statement is made by Pax at a later point (11. p. 257). This statement implies an association with other shrubs in a similar habitat, which is readily substantiated in Illinois through its association with the gooseberry (*Ribes grossularia* Linn.) and the buckthorn (*Rhamnus cathartica* Linn. and *R. lanceolatus Pursh.*) and the hawthorns (Crataegus spp).

That the presence of barberry in such shrub associations should be expected is evident from the fact that, in the first place, forest soils offer opportunity for growth in that they have been thoroughly worked over by their worm inhabitants and in that the resulting rich aeration of mould leads to the formation of highly oxidized neutral substances so that acids may form as low a proportion as one-sixteenth of the organic substance.

The presence of primeval forest on any area must preclude the possibility of shrub growths because of light relations but, following the thinning of the forest and its eventual destruction, the alteration of the light relations, and of the soil through drying out and through the dying off of its worm inhabitants, gives rise to a dry heath soil where shrub growth may take place under favorable auspices. In fact, such an environment should prove almost ideal because (9. p. 542) the edaphic conditions of the heath in cold-temperate belts give to shrub formations their most widely spread types.

It may be argued in contradiction to the foregoing that the locations indicated on our maps present a suggestion of the influence of lakes and rivers to the presence of escaped barberries, but it should be remembered that there is to be expected an increasing luxuriance of forest formations near lakes and rivers where moisture is increased by infiltration. It is noteworthy also that, in the occurrence of escaped barberries near streams,

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the shrubs are to be found almost without exception on the higher and dryer banks.

Exceptions to the suggestion contained in this paper undoubtedly occur. In three cases in Illinois, small plantings of escaped shrubs occur where it is not known that primeval forest has existed. In one instance, the shrubs grew beneath cultivated cedars of considerable age, and in the remaining two instances where fences had served as resting places for birds. These shrubs, however, were not of any great age and may be supposed to be the only remaining plants from hundreds of seeds similarly dropped throughout many square miles of land never forested; hence truly adventitious in that habitat.

RESUME

The habitat of naturalized barberry shrubs in the cold-temperate belt of the United States has been suggested as influenced by the presence or absence of calcareous soils. It is shown in the present paper that in Illinois an apparent relation between heath and "timber-soils" and barberry occurrence exists so generally as to indicate that this shrub, in becoming naturalized, seeks a characteristic shrub habitat. A practical application of this fact lies in paying particular attention to those districts characterized as having "timber soils", in the search for naturalized plantings of the common barberry.

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EXPLANATION OF FIGURES.

On Maps 1 to 8, townships are shown, and on Map 9 sections are shown.

Stars indicate the location of naturalized plantings, and figures accompanying them show the number of shrubs growing there.

Large dots indicate the location of cultivated plantings.

Stippled areas inclosed by dotted lines, indicate upland timber soil.

Map 1 Stephenson county
2 Winnebago county
3 Boone county
4 McHenry county
5 Lake county
6 Cook county
7 DuPage county
8 Kane county
9 Territory surrounding Gurnee, in Lake county, showing the spread of the common barberry from an old hedge of about 50 shrubs in the town of Gurnee.

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CONTRIBUTION TO THE FLORA OF CASS COUNTY, ILLINOIS.

FRANK C. GATES, MANHATTAN, KANSAS

From July 4 to 15, 1905, the author had the opportunity to visit at Virginia, Cass Co., Illinois. During the visit he was able to make several trips in the vicinity, collecting a number of plants and making lists of the species in various areas. It was planned to use this data in connection with some work on the Illinois Flora, but it seems advisable to publish the list now so that it will be available for use. Obviously this list of 393 species is incomplete on account of the limited time at the author's disposal.

Virginia is located at the junction of the B. & O. S. W. and C. P. & St. L. railroads in the south central part of Cass County, some 15 or so miles from the Illinois River. The country around Virginia is upland, with a few streams rising and for the most part flowing towards the Illinois River.

The accompanying sketch map indicates the area visited, the numbers corresponding to those expressed in the accompanying list of plants. Britton and Brown's "Illustrated Flora", 2nd edition, is followed rather closely in the naming of the plants, except in the grasses where Hitchcock's "Genera of Grasses" is used. The names and the arrangement of families agree with that of the natural system as exemplified by Bessey.

The specimens collected are now to be found in the herbaria of the University of Michigan, the Field Museum of Natural History, and the University of Illinois.

LIST OF PLANTS OF CASS COUNTY, ILLINOIS

Phylum—PTERIDOPHYTA.

Fam. Polypodiaceae.

Onoclea sensibilis L., 1, 3, 7, 10.
Filix fragilis (L.) Underw., 10.
Asplenium sp., 7.
Adiantum pedatum L., 7.
Pteris aquilina L., 9.

Phylum—CALAMOPHYTA.

Fam. Equisetaceae.

Equisetum arvense L., 2, 6, 8, 9.
Equisetum hyemale L., 2.
Equisetum pratense Ehrh., 2.
Equisetum laevigatum A. Br., 2, 9.

Phylum—STROBILOPHYTA.

Thuja occidentalis L., Cultivated in 5.
Juniperus virginiana L., 5.

Phylum—ANTHOPHYTA.

Class MONOCOTYLEDONEAE.

Fam. Alismataceae.

Alisma subcordatum Raf., 5, 6.
Sagittaria latifolia Willd., 5.

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LIST OF PLANTS OF CASS COUNTY, ILLINOIS—Continued.

Fam. Typhaceae.

Typha latifolia L., 2, 8.

Fam. Liliaceae.

Uvularia grandiflora J. E. Smith, 5, 10.
Hemerocallis fulva L., 5, 9.
Allium sativum L., 5.
Lilium canadense L., 1.
Erythronium albidum Nutt., 7.
Asparagus officinalis L., 6.
Vagnera racemosa (L.) Morong, 10.
Vagnera stellata (L.) Morong., 3, 7, 10.
Polygonatum biflorum (Walt.) Ell. 10.
Smilax herbacea L., 10.
Smilax hispida Muhl., 10.
Smilax sp., 1.

Fam. Commelinaceae.

Commelina virginica L., 2.
Tradescantia virginiana L., 2, 5, 9.
Tradescantia reflexa Raf., 2.

Fam. Juncaceae.

Juncus tenuis Willd., 5, 8.
Juncus brachycarpus Engelm., 1.

Fam. Araceae.

Arisaema triphyllum (L.) Torr., 3, 7, 10.
Arisaema dracontium (L.) Schott., 1, 3, 7, 10.

Fam. Cyperaceae.

Cyperus filiculmis Vahl., 3.
Eleocharis acuminata (Muhl.) Nees, 2.
Scirpus validus Vahl., 2, 6, 9.
Scirpus atrovirens Muhl., 2, 8, 9.
Scirpus lineatus Michx, 2.
Carex cephalophora Muhl., 6.
Carex davisii Schwein & Torr., 3.
Carex disperma Dewey., 10.
Carex festucacea Schkuhr, 6.
Carex frankii Kunth., 3.
Carex lanuginosa Michx., 2.
Carex laxiflora Lam., 3.
Carex rosea Schk., 10.
Carex shortiana Dewey, 2.
Carex sparganioides Muhl., 10.
Carex stipata Muhl., 10.
Carex stricta Lam., 2, 6.
Carex vulpinoidea Michx., 5, 6.

Fam. Poaceae.

Bromus ciliatus L., 3, 7, 10.
Panicularia nervata (Willd.) Kuntze, 2.
Poa alsodes A. Gray, 2.
Poa annua L., 5.
Poa compressa L., 2, 8, 9.
Poa pratensis L., 1, 2, 3, 4, 5, 7, 8, 9, 10.
Eragrostis cilianensis (All.) Link. 2.
Agropyron repens (L.) Beauv., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
Triticum aestivum L., 2, 9.
Secale cereale L., 9.
Elymus canadensis L., 1, 2, 8, 9.
Elymus hirsutiglumis Scribn., 1, 10.
Elymus virginicus L., 10.
Hystrix patula Moench., 1, 3, 7, 10.
Hordeum jubatum L., 2, 4, 5, 6, 8, 9.
Hordeum vulgare L., 2, 9.
Avena sativa L., 2, 4, 6, 8, 9.
Calamagrostis canadensis (Michx.) Beauv., 9.
Calamovilfa longifolia (Hook.) Scribn., 9.
Agrostis palustris Huds., 5, 6.
Phleum pratense L., 2, 4, 5, 6, 8, 9.
Phalaris arundinacea picta L., 5.
Syntherisma sanguinalis (L.) Dulac., 2, 5, 6, 7, 8, 9.
Paspalum debile Michx., (?) 2.
Panicum agrostoides Spreng., 5.
Panicum capillare L., 5.
Panicum depauperatum Muhl., 2.
Panicum latifolium L., 3, 10.
Panicum huachucae Ashe., 1, 3, 7, 10.
Echinochloa crusgalli (L.) Beauv., 5.
Chaetochloa italica (L.) Scribn., 2.
Chaetochloa lutescens (Weigel) Stuntz., 5.
Chaetochloa viridis (L.) Scribn., 5.
Cenchrus pauciflorus Benth., 2, 4.
Zea mays L., 2, 5, 6, 9.

Fam. Amaryllidaceae.

Hypoxis hirsuta (L.) Coville., 2.

Fam. Iridaceae.

Iris versicolor L., 2, 10.

Fam. Orchidaceae.

Cypripedium acaule Aiton. (according to residents).
Cypripedium reginae Walt., 10.
Cypripedium parviflorum Salisb., 7, 10.

Class—DICOTYLEDONEAE.

Subclass—DICOTYLEDONEAE-AXIFLORAE.

Fam. Ranunculaceae.

Hydrastis canadensis L. (according to Mr. Collins).
Delphinium ajacis L., 5.

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LIST OF PLANTS OF CASS COUNTY, ILLINOIS—Continued.

Anemone canadensis L., 3, 7, 10.
Ranunculus recurvatus Poir., 10.
Ranunculus septentrionalis Poir., 1.
Thalictrum (formerly called purpurascens), 2.
Thalictrum sp? 9.

Fam. Berberidaceae.

Podophyllum peltatum L., 1, 3, 7, 10.

Fam. Menispermaceae.

Menispermum canadense L., 3, 7.

Fam. Lauraceae.

Sassafras sassafras (L.) Karst., 1, 7. 10.

Fam. Malvaceae.

Althaea rosea L., 5, 7.
Malva rotundifolia L., 1, 2, 4, 5, 6, 7, 8, 9.
Callirhoe involucrata (T. & G.) A. Gray, 5.
Abutilon abutilon (L.) Rusby, 2, 4, 5, 6, 8, 9.
Hibiscus trionum L., 2, 4, 5, 6, 8, 9.

Fam. Tiliaceae.

Tilia americana L., 3, 5, 7, 10.

Fam. Ulmaceae.

Ulmus americana L., 3, 5, 7, 10.
Ulmus fulva Michx., 3, 10.

Fam. Moraceae.

Morus rubra L., 1.
Toxylon pomiferum Raf., 6.
Cannabis sativa L., 2, 4, 5, 9.

Fam. Urticaceae.

Urtica gracilis Ait., 3.
Urticastrum divaricatum (L.) Kuntze, 3, 10.
Pilea pumila (L.) A. Gray, 6.
Parietaria pennsylvanica Muhl., 1, 3, 5, 6, 7, 10.

Fam. Oxalidaceae.

Xanthoxalis stricta (L.) Small., 2, 5, 7.
Xanthoxalis cymosa Small., 3, 7, 10.
Xanthoxalis sp., 9.

Fam. Balsaminaceae.

Impatiens biflorum Walt., 2, 10.

Fam. Linaceae.

Linum usitatissimum L., 2, 9.

Fam. Rutaceae.

Zanthoxylum americanum Mill., 10.
Ptelea trifoliata L., 7.

Fam. Euphorbiaceae.

Croton glandulosus L., 5.
Chamaesyce maculata (L.) Small, 2, 6.
Chamaesyce preslii (Guss.) Arthur, 2.
Tithymalopsis corollata (L.) Kl. & Garcke, 2, 4, 5, 6.

Fam. Violaceae.

Viola papilionacea Pursh., 7, 10.
Viola eriocarpa Schwein., 10.

Fam. Papaveraceae (including Fumariaceae).

Bicuculla cucullaria (L.) Millsp., 7.

Fam. Brassicaceae.

Bursa bursa-pastoris (L.) Britton, 2, 4, 5, 6, 8, 9.
Radicula palustris (L.) Moench., 2, 5, 6, 9.
Armoracia armoracia (L.) Britton, 5, 6.
Lepidium virginicum L., 2, 4, 5, 6, 8, 9.
Lepidium densiflorum Schrad, 5.
Lepidium sativum L., 6.
Erysimum officinale L., 2, 4, 5, 6, 8, 9.
Norta altissima (L.) Britton., 2, 5, 6, 9.
Cardamine pennsylvanica Muhl., 2.
Sinapis alba L., 9.
Sinapis arvensis L., 5, 6, 9.
Brassica nigra (L.) Koch., 5.
Brassica campestris L., 6.
Brassica oleracea L., 2, 5, 6.
Raphanus sativus L., 2, 5.

Fam. Caryophyllaceae.

Silene stellata (L.) Ait., 10.
Silene antirrhina L., 2, 6, 8, 9.
Saponaria officinalis L., 2, 5, 9.
Vaccaria vaccaria (L.) Britton, 2.
Alsine media L., 1, 2, 5, 7.

Fam. Portulacaceae.

Claytonia virginica L., 3, 7, 10.
Portulaca oleracea L., 2, 5, 6, 7.

Fam. Aizoaceae.

Mollugo verticillata L., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

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LIST OF PLANTS OF CASS COUNTY, ILLINOIS—Continued.

Fam. Salicaceae.

Populus alba L., 5.
Populus tremuloides Michx., 1.
Populus deltoides Marsh., 2, 5.
Salix alba L., 1, 2, 10.
Salix humilis Marsh., 1.
Salix spp.

Fam. Amaranthaceae.

Amaranthus retroflexus L., 2, 4, 5, 6, 8, 9.
Amaranthus blitoides S. Wats., 5, 7.
Amaranthus graecizans L., 2.
Acnida tamariscina (Nutt.) Wood., 6.

Fam. Chenopodiaceae.

Chenopodium album L., 5, 7, 9.
Chenopodium leptophyllum (Moq.) Nutt, 5.
Chenopodium hybridum L., 5.
Cycloloma atriplicifolium (Spreng.) Coult., 2, 9.
Atriplex hastata L., 2, 5, 8, 9.
Salsola pestifer A. Nelson, 2, 4, 5, 8, 9.

Fam. Polygonaceae.

Rumex acetoselía L., 2, 5, 9.
Rumex altissimus Wood., 2.
Rumex crispus L., 2, 4, 5, 8, 9.
Rumex obtusifolius L., 10.
Polygonum aviculare L., 2, 8, 9.
Polygonum virginianum L., 7.
Persicaria lapathifolia (L.) S. F. Gray, 5.
Persicaria pennsylvanica (L.) Small, 5.
Persicaria persicaria (L.) Small, 5.
Persicaria orientalis (L.) Spach, 5.
Fagopyrum fagopyrum (L.) Karst, 5.
Tiniaria convolvulus (L.) Webb & Moq., 2, 4, 5, 8, 9.

Fam. Nyctaginaceae.

Allionia nyctaginea Michx., 9.

Fam. Plantaginaceae.

Plantago major L., 5, 6.
Plantago rugelii Dcne., 5, 6, 9.
Plantago aristata Michx., 2, 8, 9.

Fam. Ericaceae.

Vaccinium sp., 7.

Fam. Ebenaceae.

Diospyros virginiana L., 7.

Fam. Polemoniaceae.

Phlox pilosa L., 2.
Phlox divaricata L., 7, 10.

Fam. Convolvulaceae.

Ipomoea pandurata (L.) Meyer, 9.
Ipomoea purpurea (L.) Lam., 5.
Ipomoea hederacea Jacq., 2, 4.
Convolvulus sepium L., 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.
Convolvulus arvensis L., 6.

Fam. Boraginaceae.

Cynoglossum officinale L., 10.
Mertensia virginica (L.) DC., 7.

Fam. Solanaceae.

Physalis virginiana Mill., 2, 5, 8, 9.
Physalis heterophylla Nees, 9.
Solanum nigrum L., 5.
Solanum carolinense L., 2, 8, 9.
Solanum tuberosum L., 5.
Lycopersicon lycopersicon (L.) Karst, 3.
Lycium halimifolium Mill, 5.
Datura stramonium L., 1, 2, 3, 4, 5, 6, 8, 9.

Fam. Oleaceae.

Syringa vulgaris L., 5.
Fraxinus americana L., 1, 10.
Fraxinus nigra Marsh, 3.

Fam. Apocynaceae.

Apocynum androsaemifolium L., 5, 6.
Apocynum cannabinum L., 3.

Fam. Asclepiadaceae.

Asclepias tuberosa L., 2, 5, 8, 9.
Asclepias variegata L., 9.
Asclepias syriaca L., 2, 4, 5, 6, 8, 9.
Asclepias verticillata L., 2, 8.
Acerates viridiflora (Raf.) Eaton, 9.

Fam. Scrophulariaceae.

Verbascum thapsus L., 5, 9.
Scrophularia leporella Bicknell, 5.
Veronica peregrina L., 5.
Leptandra virginica (L.) Nutt., 8, 10.
Dasystoma grandiflora (Benth.) Wood, 10.

Fam. Acanthaceae.

Ruellia sp., 2, 9.

Fam. Phrymaceae.

Phryma leptostachya L., 3, 7, 10.

Fam. Verbenaceae.

Verbena urticifolia L., 4, 5, 6, 8, 9.
Verbena hastata L., 10.
Verbena angustifolia Michx., 10.
Verbena stricta Vent., 2, 4, 5, 8, 9.
Verbena bracteosa Michx., 2, 8, 9.
Lippia lanceolata Michx., 6, 10.

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LIST OF PLANTS OF CASS COUNTY, ILLINOIS—Continued.

Fam. Lamiaceae.

Teucrium canadense L., 2, 9, 10.
Teucrium occidentale A. Gray, 10.
Nepeta cataria L., 2, 5, 7.
Glecoma hederacea L., 3.
Prunella vulgaris L., 2, 9.
Leonurus cardiaca L., 5.
Stachys palustris L., 10.
Monarda fistulosa L., 8, 9.
Blephilia hirsuta (Pursh) Torr., 10.
Koellia virginiana (L.) MacM., 1, 2, 4, 7.
Lycopus virginicus L., 10.

Subclass—DICOTYLEDONEAE-CALYCIFLORAE.

Fam. Rosaceae.

Opulaster intermedius Rydb., 1, 7.
Potentilla monspeliensis L., 5, 9.
Fragaria virginiana Duchesne, 2.
Drymocallis agrimonioides (Pursh) Rydb., 9.
Agrimonia gryposepala Wallr., 1, 3, 7, 10.
Geum canadense Jacq., 5.
Geum strictum Ait., 1, 2.
Rubus strigosus Michx., 1, 7, 10.
Rubus occidentalis L., 10.
Rubus sp? (blackberry), 1, 10.
Rosa blanda Ait., 9.
Rosa virginiana Mill, 6, 9.

Fam. Malaceae.

Malus ioensis (Wood) Britton, 1, 7, 10.
Crataegus crus-galli L., 1, 7, 10.
Crataegus succulenta Schrader, 7.
Crataegus spp. (About 6 additional species.)

Fam. Prunaceae.

Prunus americana Marsh, 1, 10.
Padus nana (DuRoi) Roemer, 10.
Padus virginiana (L.) Mill, 7, 10.

Fam. Cassiaceae.

Cercis canadensis L., 3, 7, 10.
Chamaecrista fasciculata (Michx.) Greene, 2, 8, 9.
Gleditsia triacanthos L., 1, 2, 3, 5, 8, 9.

Fam. Fabaceae.

Baptisia leucantha T. & G., 6.
Melilotus alba Desv., 2, 4, 5, 6, 9.
Melilotus officinalis (L.) Lam., 5, 6.
Trifolium pratense L., 2, 4, 5, 6, 8, 9.
Trifolium hybridum L., 5, 6.
Trifolium repens L., 5, 6.
Amorpha canescens Pursh., 9.
Petalostemum candidum (Willd.) Michx., 2, 8, 9.
Petalostemum purpureum (Vent.) Rydb., 2, 8, 9.
Robinia pseudoacacia L., 5.
Meibomia nudiflora (L.) Kuntze, 10.
Meibomia grandiflora (Walt.) Kuntze, 10.
Meibomia illinoensis (A. Gray) Kuntze, 9.
Meibomia canadensis (L.) Kuntze, 2, 8, 9.
Lespedeza capitata Michx., 6.
Falcata comosa (L.) Kuntze, 1, 7, 10.
Strophostyles helvola (L.) Britton, 2, 9.

Fam. Saxifragaceae.

Penthorum sedoides L., 2, 9.
Mitella diphylla L., 10.

Fam. Grossulariaceae.

Ribes americanum Mill, 7.
Ribes sp? 5.

Fam. Hamamelidaceae.

Hamamelis virginiana L., 10.

Fam. Lythraceae.

Lythrum alatum Pursh., 2, 3, 5, 6, 8, 9.

Fam. Oenotheraceae.

Oenothera biennis L., 2, 6, 9.
Oenothera rhombipetala Nutt., 6, 9.
Kneiffia fruticosa (L.) Raimann, 9.
Circaea lutetiana L., 1, 7.
Circaea intermedia Ehrh., 3.

Fam. Cucurbitaceae.

Micrampelis lobata (Michx.) Greene, 5.

Fam. Vitaceae.

Vitis vulpina L., 3, 6, 10.
Vitis palmata Vahl, 7.
Vitis labrusca L., 10.
Parthenocissus quinquefolia (L.) Planch., 1, 3, 5, 6, 10.

Fam. Celastraceae.

Celastrus scandens L., 10.

Fam. Aceraceae.

Acer saccharinum L., 5.
Acer saccharum Marsh, 1, 3, 7, 10.
Acer negundo L., 1, 5, 10.

Fam. Anacardiaceae.

Rhus hirta (L.) Sudw., 1.
Rhus glabra L., 1, 10.
Schmaltzia crenata (Mill.) Greene, 10.

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LIST OF PLANTS OF CASS COUNTY, ILLINOIS—Concluded.

Toxicodendron radicans (L.) Kuntze 1, 2, 3, 5, 6, 7, 8, 9, 10.
Cotinus americanus Nutt., 7.

Fam. Juglandaceae.

Juglans nigra L., 1.
Hicoria ovata (Mill.) Britton, 10.
Hicoria glabra (Mill.) Britton, 1, 10.

Fam. Betulaceae.

Corylus americana Walt., 1, 7, 10.

Fam. Fagaceae.

Castanea dentata (Marsh.) Borkh., 5 (cultivated).
Quercus velutina Lam., 1, 3, 5, 10
Quercus alba L., 1, 3, 5, 10.
Quercus muhlenbergii Engelm, 10.

Fam. Araliaceae.

Panax quinquefolium L., 7.

Fam. Apiaceae.

Eryngium aquaticum L., 9.
Sanicula canadensis L., 3.
Daucus carota L., 5.
Deringa canadensis (L.) Kuntze, 3.
Pastinaca sativa L., 9.
Zizia aurea (L.) Koch, 2, 6, 8, 9.
Sium cicutaefolium Schrank, 1.
Carum carui L., 9.

Fam. Rubiaceae.

Diodia teres Walt., 6.
Galium aparine L., 1, 7, 10.
Galium circaezans Michx., 3.
Galium concinnum Torr and Gray, 10.

Fam. Caprifoliaceae.

Sambucus canadensis L., 2, 4, 7, 8, 9, 10.
Sambucus racemosa L., 10.
Viburnum lentago L., 7, 10.
Triosteum perfoliatum L., 7.
Triosteum aurantiacum Bicknell, 7.
Lonicera sp., 7.

Fam. Campanulaceae.

Campanula americana L., 10.
Specularia perfoliata (L.) A. DC., 10.
Lobelia leptostachys A, DC., 7, 10.
Lobelia inflata L., 7.

Fam. "Compositae".

Silphium perfoliatum L., 2.
Silphium laciniatum L., 8, 9.
Silphium terebinthinaceum Jacq., 2, 8, 9.
Heliopsis scabra Dunal., 5, 10.
Rudbeckia triloba L., 9.
Rudbeckia hirta L., 2, 8, 9.
Ratibida pinnata (Vent.) Barnhart, 9.
Echinacea purpurea (L.) Moench, 9, rare.
Helianthus annuus L., 5.
Helianthus atrorubens L., 2.
Helianthus occidentalis Riddell, 5.
Helianthus petiolaris Nutt, 2.
Helianthus giganteus L., 10.
Helianthus grosseserratus Martens, 2, 9.
Helianthus divaricatus L., 10.
Helianthus strumosus L., 10.
Phaethusa helianthoides (Michx.) Britton, cemetery.
Bidens sp., ? 5.
Ambrosia trifida L., 10.
Ambrosia elatior L., 2, 4, 5, 6, 8, 9.
Ambrosia psilostachya DC, 2, 9.
Xanthium sp? 2, 4, 5, 6, 8, 9.
Antennaria plantaginifolia (L.) Richards, 10.
Solidago canadensis L., 9.
Solidago nemoralis Aiton, 9.
Solidago rigida L., 9.
Chrysopsis villosa (Pursh) Nutt., 9.
Aster divaricatus L., 10.
Aster cordifolius L., 1.
Aster novae-angliae L., 10.
Aster sericeus Vent., 2.
Aster dumosus L., 2.
Erigeron pulchellus Michx., 9.
Erigeron philadelphicus L., 9.
Erigeron annuus (L.) Pers., 5.
Erigeron ramosus (Walt.) B. S. P., 5, 6.
Erigeron canadensis L., 5.
Doellingeria umbellata (Mill.) Nees, 10.
Ionactis linariifolius (L.) Greene, 9.
Vernonia fasciculata Michx., 5, 6.
Eupatorium purpureum L., 7.
Eupatorium perfoliatum L., 7.
Achillea millefolium L., 5.
Anthemis cotula L., 5, 6, 7.
Arctium minus Schk., 4, 5, 6.
Cirsium lanceolatum (L.) Hill, 4, 5, 6.
Cirsium discolor (Muhl.) Spreng., 9.
Cirsium arvense (L.) Scop., 2, 4, 5, 6, 8, 9.
Centaurea cyanus L., 5.
Taraxacum officinale Weber, 5.
Sonchus oleraceus L., 1.
Sonchus asper (L.) Hill, 5.
Lactuca virosa L., 5.
Lactuca canadensis L., 5, 7.
Lactuca sagittifolia Ell., 2, 5.
Nabalus albus (L.) Hook, 7, 10.

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THE INTRODUCED WEED FLORA OF ILLINOIS

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The more one studies the weed flora of any territory, the more one becomes convinced that there are two classes, a native and an introduced weed flora. The first class depends especially on the extent to which equilibrium has been disturbed and therefore it often becomes largely a matter of judgment as to what shall be considered a weed. This class varies with the community and the conditions. Especially does it represent a response to changed edaphic conditions. This is illustrated by such plants as Witchgrass (Panicum capillare), native species of Smartweed, Ragweed, and Cocklebur. There is no question as to whether the above plants should be classified as weeds, but the case is quite otherwise with such plants as *Asclepias incarnata, Helenium autumnale, Apocynum androesimifolium* and *Sabatia angularis,* all of which are mentioned as weeds in a prominent weed manual. Many others occur which are weeds only under certain conditions. The consideration of this class of weeds is a problem in itself. In the second class, which contains the majority of weeds in any section, the individuals are finding their balance in a new flora, rather than acting directly as a response to altered edaphic conditions, though they are undoubtedly fostered by these conditions. This is the class that is discussed in this paper. The problem of weed introduction into the state becomes a part of the larger problem of plant introduction because any foreign plant may be potentially a weed; and in order to appreciate the development of this flora in Illinois, it becomes necessary to examine records extending over nearly a century.

In 1794, Andre Michaux visited what is now the state of Illinois, in search of plants, and in his Flora Boreali-americana which appeared in 1803, he listed a number of plants as having been found "in regione Illinoensis."

In 1826, L. C. Beck, writing in Silliman's Journal, later known as "The American Journal of Science and

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Arts," published what he called "A Catalogue of the Plants of Illinois." In this list he mentions 8 plants which are now usually regarded as weeds. These are: *Cerastium vulgatum, Polygonum Convolvulus, Verbascum Thapsus, Mollugo verticillata, Solanum carolinense, Oenothera biennis, Polygonum aviculare* and *Veronica peregrina.* The first 3 are known to have been introduced into America from Europe. At least 2 of the remaining 5, *Solanum carolinense* and *Mollugo verticillata,* have probably migrated into Illinois either from the West or from the South. Two more, *Polygonum aviculare* and *Veronica peregrina,* are known to be cosmopolites. The one remaining species, *Oenothera biennis,* evidently belongs in that category of plants which assert themselves as weeds under the cultural conditions brought about by man.

The following 11 immigrants, not before mentioned, were found in 1852, either "in limited quantities" or "as single specimens," as recorded by Brendel; those found in limited quantities were *Dactylis glomerata, Digitaria humifusa, Rumex obtusifolius, Trifolium pratense* and *Veronica arvensis.* Two of these, *Rumex obtusifolius* and *Digitaria humifusa,* may become pronounced weeds. The others are inserted as members of an introduced flora. The remaining 6 were found as single specimens by Brendel in the vicinity of Peoria. They are reported by him as occurring in great abundance eighteen years later (1870). They are *Linaria vulgaris, Rumex Acetosella, Sonchus asper, Cynoglossum officinale, Lappula echinata,* and *Leonurus cardiaca.*

By 1859, many additional introduced species had been noted by various collectors. The majority of these were reported by Lapham in 1857, but several represent species added by Vasey and Brendel during the two following years. Lapham's catalogue of Illinois plants appeared in the Transactions of the Illinois State Agricultural Society. In making up the list, he states that he examined extensive collections of plants exhibited at the state fair held at Chicago in 1855. He also had the benefit of information furnished by various collectors of that period, among whom was Dr. S. B. Mead, of Han-

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cock County, who was, according to Lapham, the best recorder of Illinois plants up to 1859. Another active botanist of this period was Chas. A. Geyer, who published at least one list of Illinois plants during this interval. Dr. Engelmann, of St. Louis, furnished information concerning the flora in the southern part of the state. In regard to his catalogue, Lapham says, "It will be readily understood that the following is a pretty full list of the plants growing naturally within the state of Illinois." The great increase in additional species represents not only the fact that probably certain parts of the state were settling up rapidly, but possibly even more the stimulation of botanical interest in various parts of the state. The introduced species occurring in this list are placed below. Possibly some of those included were here in 1826, not being seen by Beck; but undoubtedly the majority came in during this period.

PLANT IMMIGRANTS FROM 1826-1859

Sisymbrium officinale
Sisymbrium Irio
Erysimum cheiranthoides
Capsella Bursa-pastoris
Brassica arvensis
Brassica nigra
Camelina sativa
Radicula Nasturtium-aquaticum
Saponaria officinalis
Saponaria Vaccaria
Agrostemma Githago
Stellaria media
Cerastium viscosum
Portulaca oleracea
Malva rotundifolia
Malva sylvestris
Malva verticillata
Sida spinosa
Abutilon Theophrasti
Hibiscus Trionum
Trifolium procumbens
Trifolium arvense
Melilotus alba
Medicago sativa
Medicago lupulina
Pastinaca sativa
Bupleurum rotundifolium
Centaurea Cyanus
Tussilago Farfara
Grindelia squarrosa
Dipsacus sylvestris
Plantago lanceolata
Verbascum Blattaria
Mentha spicata
Satureja hortensis
Melissa officinalis
Nepeta Cataria
Nepeta hederacea
Marrubium vulgare
Lithospermum arvense
Nicandra Physalodes
Cannabis sativa
Delphinium Consolida
Linum usitatissimum
Solanum Dulcamara
Rosa rubiginosa
Chenopodium murale
Chenopodium album
Chenopodium Botrys
Chenopodium ambrosioides
Chenopodium anthelminticum
Amaranthus hybridus
Amaranthus spinosus
Amaranthus retroflexus
Aethusa Cynapium
Conium maculatum
Inula Helenium
Anthemis Cotula
Chrysanthemum Leucanthemum
Cirsium arvense
Cirsium lanceolatum
Arctium minus
Taraxacum officinale
Sonchus oleraceus
Polygonum Persicaria
Polygonum orientale
Rumex crispus
Fagopyrum esculentum

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PLANT IMMIGRANTS FROM 1826-1859—Concluded

Eleusine indica	Echinochloa crusgalli
Eragrostis megastachya	Digitaria sanguinalis
Bromus secalinus	Setaria glauca

The above list contains 74 introduced species, most of them probably coming in during the interval of 33 years. Several of these were possibly introduced originally as crop plants or vegetables, such as *Medicago sativa, Pastinaca sativa, Linum usitatissimun, Cannabis sativa* and *Fagopyrum esculentum.* Several are medicinal plants, ornamentals, or plants of the old-fashioned garden, such as *Marrubium vulgare, Melissa officinalis, Satureja hortensis, Mentha spicata, Nepeta Cataria, Centaurea Cyanus, Delphinium Consolida, Polygonum orientale, Rosa rubiginosa* and *Aethusa Cynapium.* The remaining species are mostly weeds, the worst possibly being *Cirsium arvense.* The greatest number of introductions was in the family Compositae, with the Cruciferae second.

In 1870, Frederick Brendel, working mainly in the region near Peoria, published an article in the American Entomologist and Botanist entitled, "Distribution of Immigrant Plants." He notes the following—heretofore not mentioned—as "adventitious plants" or "mostly escaped or purposely introduced:—"

Argemone mexicana	Tanacetum vulgare
Nasturtium Armoracia	Ipomoea purpurea
Anethum graveolens	Phalaris canariensis
Helianthus annuus	Setaria italica

The following additional plants, he says, had been naturalized from an unknown date:—

Hypericum perforatum	Phleum pratense
Chenopodium urbicum	Agrostis alba
Alepecurus pratensis	Poa compressa

In this list he also mentions *Plantago major, Chenopodium hybridum, Solanum nigrum* and *"Xanthium strumarium",* all of which are now regarded as indigenous or at least as cosmopolites. *Raphanus raphanistrum* is mentioned as having been found in 1852, but not seen since. Many of the introduced species mentioned by Brendel had already appeared in Lapham's catalogue.

In 1872, H. H. Babcock's "Flora of Chicago and Vicinity" appeared. In this he mentions 47 introduced

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plants, all found within 40 miles of Chicago. The following are named in addition to those already mentioned in previous lists:—

Lycopus europaeus
Datura Stramonium
Festuca elatior
Hordeum jubatum
Agropyron repens
Setaria viridis
Callirhöe involucrata

The last two are possibly indigenous to the state. It is interesting to note that this is the first mention made of *Agropyron repens.*

In 1891, the "Flora of Cook County" by Higley and Raddin came out. It listed a total of 1223 species. In the interval between 1872 and 1891, many new species were introduced, several of which were noted by E. J. Hill, one of the most active collectors in the Chicago region during this period. In 1871, another list was published by J. W. Hewitt in the National History of Illinois, LaSalle County. This contained several more introduced species. The following list contains those species which apparently came in during this interval, a period of 25 years. For convenience the various species are collected into their respective families. The exact year for several of the species is given in the articles consulted. For example, J. E. Arthur, in 1883, was possibly the first to call attention to the appearance in this region of *Galinsoga parviflora.*

1872-1897.

Setaria verticillata
Panicum miliaceum
Eragrostis minor
Lolium perenne
Agropyron biflorum
Agropyron caninum
Cynodon Dactylon
Bromus tectorum
Bromus racemosus
Hemerocallis fulva
Muscari botryoides
Allium vineale
Urtica dioica
Salsola Kali
Cycloloma atriplicifolium
Chenopodium glaucum
Chenopodium Bonus-Henricus
Amaranthus graecizans
Amaranthus blitoides
Amaranthus paniculatus
Oxybaphus nyctagineus
Silene latifolia
Silene noctiflora
Lychnis alba
Arenaria serpyllifolia
Spergula arvensis
Ranunculus bulbosus
Radicula sylvestris
Sisymbrium altissimum
Lepidium campestre
Lepidium sativum
Lepidium intermedium
Conringia orientalis
Draba verna
Alyssum maritumum
Alyssum alyssoides
Isatis tinctoria
Neslia paniculata
Reseda alba
Sedum acre
Sedum purpureum
Sempervivum tectorum
Hosackia americana

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Trifolium hybridum
Trifolium stoloniferum
Lespediza striata
Melilotus officinalis
Euphorbia Cyparissias
Ricinus communis
Malva moschata
Gaura parviflora
Carum Carvi
Daucus Carota
Lysimachia Nummularia
Anagallis arvensis
Convolvulus arvensis
Ipomoea Hederacea
Ipomoea coccinea
Myosotis scorpioides
Verbena officinalis
Leonurus sibirica
Galeopsis Tetrahit
Solanum rostratum
Physalis barbadensis
Datura Tatula
Nicotiana rustica
Veronica agrestis
Lactuca scariola
Tragopogon porrifolius
Tragopogon pratensis
Galinsoga parviflora
Anthemis arvensis
Chrysanthemum Parthenium
Cichorium Intybus
Sonchus arvensis
Centaurea Jacea
Artemisia annua
Aster angustus
Anthemis nobilis
Chrysanthemum Balsamita
Artemisia longifolia
Leontodon autumnalis
Hieracium aurantiacum

A large number of species in the above list are common weeds of European nativity. A few are species which have come in from the West, such as *Gaura parviflora, Amaranthus blitoides, Hosakia americana, Solanum rostratum,* and possibly *Cycloloma atriplicifolia.* Two species of Agropyron, *A. caninum* and *A. biflorum,* are supposed to have come in from the North or Northwest. They are not common. There are several species originally from the tropics, such as *Amaranthus paniculatus, Datura Tatula, Galinsoga parviflora,* and *Ricinus communis.* Plants evidently escaping from cultivation are, *Tragopogon porrifolius, Lespediza striata, Trifolium hybridum, Melilotus officinalis, Cichorium Intybus, Chrysanthemum Parthenium, Alyssum maritimum, Alyssum alyssoides, Lepidium sativum, Reseda alba, Hemerocallis fulva, Muscari botryoides, Myosotis scorpioides, Ipomoea coccinea, Daucus Carota, Carum Carvi, Sedum purpureum, Sempervivum tectorum* and probably a few others. *Isatis tinctoria,* the English Woad, was found at one point in Chicago. Several others mentioned above are quite rare. *Sisymbrium altissimum,* one of the most notorious of the tumble weeds, appears to have been noticed first about 1890. The greatest number of species for any family during this period is in the Cruciferae, with 9 representatives.

The interval from 1897 to 1921 may be taken conveniently as the last period. The number of introductions

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during this period was somewhat less than during the preceding interval. A noticeable feature is the number of species which have come from the West. Several of these have not yet spread far from the railroads, where one would expect the conditions for acclimitization were not the best. The writer is indebted to Dr. H. S. Pepoon, of the Lake View High School, Chicago, for the following list of plants coming in during this time.

1897-1921.

Sorghum halepense
Avena fatua
Bromus hordeaceus
Bromus inermis
Rumex elongatus
Atriplex argentea
Spergularia mariana
Stellaria aquatica
Lychnis coronaria
Gypsophila muralis
Ranunculus acris
Chelidonium majus
Thlaspi arvense
Camelina microcarpa
Raphanus sativus
Brassica alba
Brassica juncea
Brassica Napus
Brassica campestris
Diplotaxis muralis
Hesperis matronalis
Barbarea vulgaris
Erysimum asperum
Polanisia trachysperma
Potentilla recta
Crotallaria sagittalis
Trifolium incarnatum
Trifolium agrarium
Kallstroemia maxima
Euphorbia marginata
Euphoribia Peplus
Oenothera pallida
Oenothera speciosa
Oenothera serrulata
Cynanchum nigrum
Cuscuta Epilinum
Gilia linearis
Echium vulgare
Verbena bipinnatifida
Lamium maculatum
Lamium amplexicaule
Leonurus Marrubiastrum
Mentha rotundifolia
Solanum elaeagnifolium
Physalis Alkekengi
Physalis pumila
Physalis longifolia
Lycium halimifolium
Petunia violacea
Plantago aristata
Iva xanthifolia
Lepachys columnaris
Coreopsis tinctoria
Artemisia kansana
Artemisia vulgaris
Artemisia procera
Geranium pusillum
Tribulus terrestris
Arctium minus

An examination of the foregoing list reveals several points of interest. Nearly one-third of the species are introductions from the West. *Barbarea vulgaris, Aster angustus* and *Spergularia mariana* are cosmopolites. The first is thought to be indigenous to the Northwest, and to have spread eastward. The case of *Spergularia mariana* is interesting. It is a plant of the Atlantic and Pacific seaboards, and saline regions of the interior, according to Gray's Manual. The tendency to spread eastward is rather striking in the two families Solanaceae and Onagraceae. Plants evidently escaping from cultivation are *Sorghum halepense, Bromus inermis, Lychnis*

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coronaria, Raphanus sativus, Brassica alba, Brassica Naus, Brassica campestris, Hesperis matronalis, Trifolium incarnatum, Physalis Alkekengi, Petunia violacea, Coreopsis tinctoria, Lycium halimifolium, and possibly *Euphorbia marginata* and *Cynanchum nigrum.* The following, besides two or three already mentioned, are immigrants from the West: *Atriplex argentea, Erysimum asperum, Crotallaria sagittalis, Oenothera pallida, Oenothera speciosa, Oenothera serrulata, Verbena bipinnatifida, Solanum elaeagnifolium, Physalis pumila, Physalis longifolia, Plantago aristata* (probably), *Iva xanthifolia, Lepachys columnaris, Artemisia kansana, Polanisia trachysperma,* and probably *Kallstroemia maxima* and *Gilia linearis.* The following is a list by families of the entire introduced flora enumerated in the preceding pages. Shrub and tree introductions, such as *Populus alba, Salix alba,* etc., are excluded, as they are hardly to be counted as weeds. It is realized that the list is probably not complete. The nomenclature is that of Gray's Manual, 7th edition.

GRAMINEAE

Eleusine indica, an., Old World trop.
Eragrostis magastachya, an., Eur.
Eragrostis minor, an., Eur.
Digitaria sanguinalis, an., Eur.
Digitaria humifusa, an., Eur.
Setaria glauca, an., Eur.
Setaria viridis, an., Eur.
Setaria verticillata, an., Eur.
Setaria italica, an., Eur.
Echinochloa crusgalli, an., Eur.
Bromus secalinus, an., Eur.
Bromus hordeaceus, an., Eur.
Bromus tectorum, an., Eur.
Bromus racemosus, an., Eur.
Bromus inermis, per., Eur.
Dactylis glomerata, per., Eur.
Poa annua, an., Eur.
Poa compressa, per., Eur.
Phalaris canariensis, an., Eur.
Agropyron repens, per., Eur.
Agropyron biflorum, per., Amer.
Agropyron caninum, per., Amer.
Hordeum jubatum, an., Cosmop.
Festuca elatior, per., Eur.
Lolium perenne, per., Eur.
Cynodon Dactylon, per., Eur.
Panicum miliaceum, an., Eur.
Avena fatua, an., Eur.

GRAMINEAE—Concluded

Sorghum halepense, per., Eur.
Phleum pratense, per., Eur.
Agrostis alba, per., Cosmop.
Alopecurus pratensis, per., Eur.

LILIACEAE

Hemerocallis fulva, per., Eur.
Muscari botryoides, per., Eur.
Allium vineale, per., Eur.

URTICACEAE

Urtica dioica, per., Eur.
Cannabis sativa, an., Asia.
Humulus Lupulus, per., Cosmop.

POLYGONACEAE

Polygonum Convolvulus, an., Eur.
Polygonum Persicaria, an., Eur.
Polygonum orientale, an., India.
Polygonum aviculare, an., Cosmop.
Rumex Acetosella, per., Eur.
Rumex crispus, per., Eur.
Rumex elongatus, per., Eur.
Rumex obtusifolius, per., Eur.
Fagopyrum esculentum, an., Eur.

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CHENOPODIACEAE

Chenopodium album, an., Eur.
Chenopodium murale, an., Eur.
Chenopodium Botrys, an., Eur.
Chenopodium ambrosioides, an., Trop. Amer.
Chenopodium anthelminticum, an., Trop. Amer.
Chenopodium urbicum, an., Eur.
Chenopodium Bonus-Henricus, an., Eur.
Chenopodium glaucum, an., Eur.
Cycloloma atriplifolium, an., Amer.-west.
Atriplex argentea, an., Amer.-west.
Salsola Kali, an., Eur.

AMARANTHACEAE

Amaranthus retroflexus, an., Trop. Amer.
Amaranthus paniculatus, an., Trop. Amer.
Amaranthus spinosus, an., Trop. Amer.
Amaranthus hybridus, an., Trop. Amer.
Amaranthus blitoides, an., Amer. west.
Amaranthus graecizans, an., Amer.-west?

NYCTAGINACEAE

Oxybaphus nyctagineus, per., Amer.-west.

AIZOACEAE

Mollugo verticillata, an., Amer.-south.

CARYOPHYLLACEAE

Cerastium vulgatum, per., Eur.
Cerastium viscosum, an., Eur.
Saponaria officinalis, per., Eur.
Saponaria Vaccaria, an., Eur.
Agrostemma Githago, an., Eur.
Stellaria media, an., Eur.
Stellaria aquatica, per. Eur.
Arenaria serpyllifolia, an., Eur.
Silęne latifolia, per. Eur.
Silene noctiflora, an., Eur.
Lychnis alba, an., Eur.
Lychnis coronaria, per., Eur.
Spergula arvensis, an., Eur.
Spergularia mariana, an., Cosmop.
Gypsophila muralis, an., Eur.

PORTULACACEAE

Portulaca oleracea, an., Eur.

RANUNCULACEAE

Ranunculus bulbosus, per., Eur.
Ranunculus acris, per., Eur.
Delphinium Consolida, an., Eur.

PAPAVERACEAE

Chelidonium majus, bien., Eur.
Argemone mexicana, an., Mex.

CRUCIFERAE

Sisymbrium officinale, an., Eur.
Sisymbrium Irio, an., Eur.
Sisymbrium altissimum, an., Eur.
Erysimum cheiranthoides, bien., Amer.
Erysimum asperum, bien., Amer.
Capsella Bursa-pastoris, an., Eur.
Brassica arvensis, an., Eur.
Brassica nigra, an., Eur.
Brassica alba, an., Eur.
Brassica juncea, an., Asia.
Brassica Napus, an., Eur.
Brassica campestris, an., Eur.
Radicula Nasturtium-aquaticum, per., Eur.
Camelina sativa, an., Eur.
Camelina microcarpa, an., Eur.
Radicula sylvestris, per., Eur.
Lepidium campestre, an., Eur.
Lepidium sativum, an., Eur.
Lepidium intermedium, an., Eur.
Conringia orientalis, an., Eur.
Draba verna, an., Eur.
Alyssum maritimum, an., Eur.
Alyssum alyssoides, an., Eur.
Nasturtium Armoracia, per., Eur.
Neslia paniculata, an., Eur.
Isatis tinctoria, bien., Eur.
Thlaspi arvense, an., Eur.
Raphanus sativus, an., Eur.
Raphanus raphanistrum, an., Eur.
Hesperie matronalis, bien. (or per.), Eur.
Barbarea vulgaris, per., Amer. and Eur.
Diplotaxis muralis, an., Eur.

CAPPARIDACEAE

Polanisia trachysperma, an., Amer.

RESEDACEAE

Reseda alba, an., Eur.

CRASSULACEAE

Sedum acre, per., Eur.
Sedum purpureum, per., Eur.
Sempervivum tectorum, per., Eur.

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ROSACEAE

Potentilla recta, per., Eur.
Rosa rubiginosa, per., Eur.

LEGUMINOSAE

Trifolium procumbens, an., Eur.
Trifolium arvense, an., Eur.
Trifolium hybridum, per., Eur.
Trifolium stoloniferum, per., Amer.-west.
Trifolium incarnatum, an., Eur.
Trifolium agrarium, an., Eur.
Trifolium pratense, per., Eur.
Cassia Tora, an., Amer.-south.
Melilotus alba, an. (or bien.), Eur.
Melilotus officinalis, an., (or bien.), Eur.
Medicago sativa, per., Eur.
Medicago lupulina, an., Eur.
Lespediza striata, an., E. Asia.
Hosackia americana, an., Amer.-west.
Crotallaria sagittalis, an., Amer.

LINACEAE

Linum usitatissimum, an., Eur.

GERANIACEAE

Geranium pusillum, an., Eur.

ZYGOPHYLLACEAE

Tribulus terrestris, an., Old World.
Kallstroemia maxima, an., Amer. s. w.

EUPHORBIACEAE

Euphorbia Cyparissias, per., Eur.
Euphorbia Peplus, an., Eur.
Euphorbia marginata, an., Amer.-west.
Ricinus communis, an., Old World Trop.

MALVACEAE

Malva rotundifolia, per., Eur.
Malva sylvestris, bien., Eur.
Malva verticillata, an., Eur.
Malva moschata, per., Eur.
Sida spinosa, an., Trop.
Abutilon Theophrasti, an., India.
Hibiscus Trionum, an., Eur.

HYPERICACEAE

Hypericum perforatum, per., Eur.

ONAGRACEAE

Gaura parviflora, Amer.-west.
Oenothera pallida, per., Amer.-west.
Oenothera speciosa, per., Amer.-west.
Oenothera serrulata, per., Amer.-west.

UMBELLIFERAE

Pastinaca sativa, bien., Eur.
Bupleurum rotundifolium, an., Eur.
Aethusa Cynapium, an., Eur.
Conium maculatum, bien., Eur.
Carum Carvi, bien., Eur.
Daucus Carota, bien, Eur.
Anethum graveolens, an., Eur.

PRIMULACEAE

Lysimachia Nummularia, per., Eur.
Anagallis arvensis, an., Eurasia.

ASCLEPIADACEAE

Cynanchum nigrum, per., Eur.

CONVOLVULACEAE

Convolvulus arvensis, per., Eur.
Cuscuta Epilinum, an., Eur.
Ipomoea coccinea, an., Trop. Amer.
Ipomoea hederacea, an. Trop. Amer.
Ipomoea purpurea, an., Trop. Amer.

POLEMONIACEAE

Gilia linearis, an., Amer.-west.

BORAGINACEAE

Echium vulgare, bien., Eur.
Cynoglossum officinale, bien., Eur.
Lappula echinata, an., Eur.
Lithospermum arvense, an., Eur.
Myosotis scorpioides per., Eur.

VERBENACEAE

Verbena bipinnatifida, per., Amer.-west.
Verbena officinalis, an., Eur.

LABIATAE

Leonurus cardiaca, per., Eur.
Leonurus sibirica, bien., Eur.
Leonurus Marrubiastrum, bien., Eur.
Satureja hortensis, an., Eur.
Melissa officinalis, per., Eur.
Nepeta Cataria, per., Eur.

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LABIATAE—Concluded

Nepeta hederacea, per., Eur.
Marrubium vulgare, per., Eur.
Galeopsis Tetrahit, an., Eur.
Lamium maculatum, per., Eur.
Lamium amplexicaule, an. (or bien.), Eur.
Mentha spicata, per., Eur.
Mentha rotundifolia, per., Eur.
Lycopus europaeus, per., Eur.

SOLANACEAE

Solanum carolinense, per., Amer. west.
Solanum rostratum, an., Amer.-west.
Solanum nigrum, an., Cosmop.
Solanum elaeagnifolium, per., Amer.-west.
Solanum Dulcamara, per., Eur.
Nicandra Physalodes, an., A. Amer.
Physalis barbadensis, an., Amer.-west.
Physalis Alkekengi, per., E. Asia.
Physalis pumila, per., Amer.-west.
Physalis longifolia, per., Amer.-west.
Lychium halimifolium, per., Eur.
Petunia violacea, an., Trop. Amer.
Datura Stramonium, an., Trop. Amer.
Datura Tatula, an., Trop. Amer.
Nicotiana rustica, an., Amer. (probably).

SCROPHULARIACEAE

Linaria vulgaris, per., Eur.
Verbascum Thapsus, bien., Eur.
Verbascum Blattaria, bien., Eur.
Veronica agrestis, an., Eur.
Veronica arvensis, an., Eur.

PLANTAGINACEAE

Plantago lanceolata, per., Eur.
Plantago aristata, an., Amer.-west.

DIPSACACEAE

Dipsacus sylvestris, Bien., Eur.

COMPOSITAE

Sonchus asper, an., Eur.
Sonchus oleraceus, an., Eur.
Sonchus arvensis, per., Eur.
Tussilago Farfara, per., Eur.
Grindelia squarrosa, per., Amer.-west.
Arctium minus, bien., Eur.
Taraxacum officinale, per., Eur.
Centaurea Cyanus, an., Eur.
Centaurea Jacea, per., Eur.
Hieracium aurantiacum, per., Eur.
Inula Helenium, per., Eur.
Anthemis Cotula, an., Eur.
Anthemis nobilis, per., Eur.
Anthemis arvensis, an. (or bien.), Eur.
Chrysanthemum Leucanthemum, per., Eur.
Chrysanthemum Balsamita, per., Asia.
Chrysanthemum Parthenium, per., Eur.
Cichorium Intybus, bien., Eur.
Cirsium arvense, per., Eur.
Cirsium lanceolatum, per., Eur.
Aster angustus, an., Amer.-west.
Leontodon autumnalis, per., Eur.
Lactuca scariola, an., Eur.
Tragopogon porrifolius, bien,, Eur.
Tragopogon pratensis, bien., Eur.
Galinsoga parviflora, an., Trop. Amer.
Artemisia longifolia, per., Amer.-west.
Artemisia kansana, per., Amer.-west.
Artemisia vulgaris, per., Eur.
Artemisia procera, per., Eur.
Artemisia annua
Coreopsis tinctoria, an., Amer.-west.
Lepachys columnaris, per., Amer.-west.
Iva xanthifolia, an., Amer.-west.
Helianthus annuus, an., Amer.-west.
Tanacetum vulgare, per., Eur.

The data for nativity and duration of the above species were taken from Gray's Manual, 7th edition. The duration of several species, especially those belonging to the Cruciferae, may vary considerably from annual to bien-

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nial. The total number of introduced species listed above is 256. Undoubtedly there are several others which should be included. These figures, however, will serve as a basis for estimating the relative weed introduction from various sources. On this basis, 73% are of European origin, 14% come in from West of the Mississippi, 6% are of Tropical American origin, 5% are of Asiatic origin, and 2% are cosmopolitan. As to duration, approximately 32% are perennial, 60% annual and 8% biennial. Every species from Tropical America without exception acts here as an annual, which is to be expected.

The greatest number came in during the period from 1872 to 1897. Apparently the number of introductions during the last 24 years have been 30% less than the number during the preceding 25 years, the average being 2.4 per year as against 3.3 yearly for the preceding interval. The period from 1872 on no doubt represents a rapid settling up of the farmlands of the state, and is naturally correlated with the introduction of many new species. The observations of Dr. H. S. Pepoon, one of the most thorough-going students of the flora of the state, are in line with this supposition. In 1876 he noted 355 species in a certain farm, and on the same farm in 1904, only 200, and these, he says, in his observations at the time "are the plebians, toughs, tramps, and rabble. The royal ones are gone."

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THE EUROPEAN STARLING IN ILLINOIS

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The presence of a small flock of European starlings at Urbana, Illinois, during the past winter, naturally leads to a desire to know something of the characteristics of this recent alien addition to our bird fauna. During the two decades following their first successful introduction into this country, in 1890, starlings did not extend their range much more than 200 miles from New York City where they were originally introduced. During the past decade they have made much more rapid progress, and have been reported from Nova Scotia, Canada, Ohio, Alabama, Georgia, and intermediate states, and have become abundant in various parts of New England, New York, and Pennsylvania. They seem destined to become abundant in the Mississippi Valley.

They are very valuable aids in the destruction of a great variety of insect pests, but, when abundant, do extensive damage to fruit. They nest in holes and interfere seriously with various kinds of birds using such nesting places. Like the English sparrows, they are more commonly to be found about the habitations of man. A considerable part of the starling population is ordinarily migratory, going southward for the winter. They need and should receive no legislative protection.

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ECOLOGICAL SURVEY OF THE FAUNA OF LAKE KNOX

FLORENCE ADCOCK, KNOX COLLEGE

I. Description of the Lake.
II. Reasons for choosing this particular region for our ecological survey.
III. Purpose in the work to make as extensive a survey as possible, in the limited time, of the fauna of the lake and the conditions affecting the life of the lake.
IV. Methods.
V. Ecology.
VI. General Survey of the Fauna with ecological notes.

Lake Knox is a small, artificial lake or pond almost triangular in shape; and is 380 feet long, 210 feet wide at the wider end and 90 feet wide at the other. It lies in an east and west direction and is situated beside the Sante Fe railroad track two and a half miles east of Galesburg, Knox County, Illinois. The lake, which is 750 feet above sea level, is artificial and dates back to about 1880, when it was made by Purington Brick Company to supply water for their brick works. The pond is very shallow, being about eight or ten feet deep; but there is a seasonal change of several feet due to spring rains and summer drought. The water supply is largely surface water which drains in after rains. Two springs also contribute to the water of the pond; of these one empties directly through a pipe from a well just a few feet south of the railroad track, midway on the south side; while the other, which is about one-quarter mile south of the lake, drains into it through a creek and another pond. The stream enters the pond at the southeast corner. The lake is drained by a large pipe running under the street car track 75 feet from the east end of the north side and by a small pipe under the south end of the east embankment.

The banks of the pond are partly of bricks and cinders, especially the south bank where the railroad company

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empties cinders, thus helping to fill up the lake. The pond if undisturbed will gradually fill up with humus formed by plants that die and by silt washed in by the small stream. Besides the area above described, this survey includes a swampy region about twenty feet east of the east end of Lake Knox (a little road separating it from the lake). This area has developed in the last five years. In this swamp are many cat tails, and muskrat mounds are quite numerous.

The reasons for choosing this particular pond for this ecological survey were (1) because it is small and thus better suited for making an extensive study; (2) because it seemed like a typical place for the study of pond life; (3) because it is accessible, being not far from college and on the street car line; (4) because of the great abundance of aquatic life found there.

The purpose in this study is to make as extensive a survey as possible, in the limited time, of the fauna of the pond and its life. An attempt has been made (1) to study the environmental conditions which pertained to the life of the animals; (2) to identify by means of a key the specimens found therein, and (3) to study their habits in relation to their environment.

Methods: In order to collect systematically, definite stations were established from which specimens were collected once a week by means of a long handled dip net; these specimens, together with some of the mud, algae, etc., were put in fruit jars and small bottles and brought to the laboratory. The material was then examined; some specimens were preserved at once in 70% alcohol while some were kept alive in large jars for further study of their habits, and development of larval forms. Most of the collecting was done on Saturday, but the work of study and identification was done during the week with the aid of a lens, binoculars and microscope.

Five stations were established. (I) The swiftly flowing brick-bottomed stream, which entered the lake at the southeast corner, together with the muddy area immediately adjacent was selected. For this station an area ten feet square was measured. (11) A shallow station west of station I where the water flows in through

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a pipe at the rate of about 13 pints a minute became station II. The area is only a few feet wide and is clear, fresh water, the bottom being covered with dead grass and other vegetable matter. (III) A station at the northwest corner of the area called the muskrat region is Station III. There the shallow stream flows slowly under a bridge. The station is a mud bottomed one with a few bricks near the bridge. (IV) This station is located at the outlet which is west of Station III. Here the water flows rather swiftly through two large pipes which are beneath the street car track. Here are found a number of large stones, two large cement blocks and a floating log. (V) This area is of sluggish water which flows from a tile on the east side of the little road. This station is located just north of Station III. The water is rich in algae. In places it has a film due to a certain kind of bacteria.

In studying animals as they exist in nature, one cannot overlook the fact that conditions of environment have much to do with the life of any region. Animals of a pond are influenced by such physical factors as the character of the surrounding country, the movement and the depth of the water, the character of the bottom and of the shores, and the light, temperature, and winds. Furthermore, animal life is influenced by such chemical factors as the acidity or alkalinity of the water and the presence of gases, salts, etc., in the water. Food and biological environment also affect pond life. The surrounding country is rich land of a glaciated region. It would seem, then, that a large amount of food materials might be carried into the lake by the contributing streams. There are small hills near, and a small patch of timber, thus limiting the effect of winds. Winds have a decided effect upon the life of a lake for they keep the water moving. In the rainy season of March and April the water is high and the inflowing stream is rapid. But in the dry season of mid-summer there is only a trickle and the lake is very low. The pond bottom is largely muck composed of decayed animal and vegetable debris. This muck is quite deep, for one sinks in it several feet.

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The underlying soil is shale, above which is the formation of ooze of animal and vegetable debris.

The water of the pond is comparatively clear so that light can penetrate to the bottom. In the muskrat region, however, the water is more muddy in appearance but is more shallow so that light can easily penetrate. The winter was not severe but the lake was covered with ice most of the time until the last of February. The first killing frost was October 29th and the last frost, which was a slight one, was April 23rd.

Much of the wind is kept off by the surrounding hills and by the banks which are three or four feet higher than the surface of the water. Wind is an important factor in determining the circulation of the water which affects living organisms.

Chemical Conditions of Water. Water was taken about three inches below the surface at a distance of a few feet from the shore, on a slightly cloudy day. The chemical tests were made by Professor J. E. Neifert, Department of Chemistry, Knox College. He found the oxygen content very low, 5.2 parts per million by weight. The hardness in $CaCO_3$ units was 168 parts per million and the alkalinity was 205 parts per million.

The character of the margin (whether rocky or swampy), that of the shore (whether steep or shallow), the outline (whether smooth or jagged), the depth of the lake, the chemical content of the soil, the banks, the exposure to sun and wind, relative inflow and outflow in relation to volume, the altitude, and the geographic location—all these factors modify and control the types of living things and their abundance in the water.

Lakes are only temporary; inflowing water brings detritus which fills in the shore for a new kind of vegetation. This region increases as the lake advances in age, and open water and bottom areas decrease likewise till a swamp results which is gradually reduced to dry land.

Life in the lake changes as the lake changes. At first there is little fauna, but it increases as new habitats are formed. Raw materials are washed in and plants and

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animals increase. Animals are dependent upon each other; some supply food, some are enemies, etc. Man likewise has much influence upon the life of the pond. Animals also are dependent upon the amount and kind of vegetation, for plants are used for places to secure food, clinging places, sources of oxygen, shade and breeding places.

Animals thus form communities according as they select the same kind of habitat. In ponds the following habitats may usually be recognized. (1) The littoral or shallow water area along the shore comprising both that of (a) emergent vegetation and (b) that of submerged vegetation; and (2) the pelagic or open water area where fixed vegetation is lacking. The plants and animals of this area are called *Plankton*. They remain suspended on the surface of the water. There may be another open water society called *Necton* which refers to large free swimming forms. The emergent vegetation area is lacking in Lake Knox, but is evidenced in the muskrat region. The area of submerged vegetation is found on the north side, where Elodea is rather abundant and also at Station V where algae are so abundant.

GENERAL SURVEY OF THE FAUNA OF LAKE KNOX.

Phylum *Protozoa*

All the protozoa identified were found in an aquarium of water collected from the pond.

1. *Sarcodina*

Class *Rhizopoda*

Only two classes of the so-called pseudopodia bearing organisms were found.

Amoeba proteus

These were few in number.

Arcella vulgaris

This is a green, smooth shelled *Rhizopod*. They were not abundant.

2. *Mastigophora*, the flagellates

Euglena viridis

Only one specimen was seen.

Volvox

Was rather more abundant.

3. Infusoria

Class *Ciliata*

Order *Holotricha*

Two specimens of *Paramoecium* were found.

Paramoecium caudatum, a large protozoan, was very abundant on the surface of the small jar of water. The specimens were so large that they were easily seen with the naked eye.

Paramoecium aurelium

Was found in a similar situation though not so abundant.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued

3. Infusoria—Concluded

Order *Heterotricha*

Spirostomum (rare)

Stentor polymorphus

An attached form, only a few specimens of which were seen.

Order *Hypotricha*

Stylonichia

Order *Peritricha*

Vorticella campanula

This well known vorticella was found also many times among the Elodea of Station IV.

Carchesium, a colony vorticella, was found on a beetle larva. This form contracts independently.

Zoothamium

Contract together and were found on the legs of a dead crustacean (*gammarus*).

Phylum *Porifera*

No fresh water sponges were found, but they are reported as having been found there.

Phylum *Coelenterata*

Order *Hydrazoa*

Fresh water hydra were found in the pond several times but the exact station was not known. They were seen attached to the bottom of the glass dish in which the water was placed.

Hydra viridis

Green hydra.

Hydra vulgaris

Whitish hydra.

Phylum *Plathelminthes*

Class *Turbellaria*

Planaria tova

This almost black worm was found in great numbers at Station II among the dead grasses at the bottom.

Planaria velata

Is a much larger whitish one measuring 16 mm. in length. This was found at the same station.

Class *Trematodes*

Two kinds were found but were not identified. One was a small pinkish one on a *Gammarus*. The other, longer and more slender, was parasitic on the swimmerets of the crayfish.

Phylum *Nemathelminthes*

Class *Gordiacea*

Paragordus varius

This small hair worm was the only round worm found. It was a small worm with a white head and a dark band behind the head; and was found near the surface of the water at Station V.

Phylum *Trochelminthes*

Class *Rotifera*

Order *Bdelloida*

Family *Philodinidae*

Rotifer vulgaris

Philodina

Both of these species were found in the jar of water mentioned.

Phylum *Bryozoa*

No bryozoans were found during the survey.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Annelida*
Class *Chaetopoda*
Order *Oligochaeta*
Family *Lumbricidae*
Helodrilus caliginosus
The common earth worm was found frequently on damp earth on the bank.
Family *Naididae*
Chaetogaster
Several of these were found in the shallow water of Station I.
Class *Hirudinea*
Order *Gnathobdellida*
Family *Herpobdellidae*
Herpobdella punctata
This leech was found in numbers attached to the under surface of bricks at the mud bottomed station in the muskrat region. It was a rather large form characterized by four rows of black spots on the dorsal side. About the middle of May they were found in great numbers at Station I. The little newly hatched ones were very numerous on the under side of bricks in the water, and eggs were plentiful as well.

Phylum *Arthropoda*
Class *Crustacea*
Subclass *Entomostraca*
Order *Phyllopoda*
Suborder *Cladocera*
These water fleas were found in the water of Station V where plant food is so abundant.
Simocephalus
Daphnia
Both of these forms were found in shallow water, sometimes on the surface, and sometimes deeper in the water. Daphnia was the more numerous of the two.
Order *Copepoda*
Cyclops bicuspidatus
This was found very early in the spring, in fact as early as March 20th when the water was quite cold. It is a plankton form remaining on the surface. It is found at almost all seasons of the year and often bears great loads of eggs in two little sacs, one on either side near the posterior end of the body.
Order *Ostracoda*
Cypris virens
These small animals, which are enclosed by a shell, belong to the plankton of the pond. The shell is covered with hairs.
Subclass *Malacostraca*
Order *Amphipoda*
Gammarus faciatus
This small crustacean was found in March and early April in great numbers in the bottom of Station V and also at Station I. They seem to be unable to survive when taken out of their habitat, for they die very quickly when put in jars of water in the laboratory.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Arthropoda*—Continued

Order *Isopoda*

Family *Asellidae*

Asellus communis

This was very common among decaying vegetable matter of Station II and also of Station III. They were found in puddles of the Muskrat Region in early March while ice was still on. Young ones were very numerous on the under side of stones at Station I, May 28th.

Oniscus asellus

The common sow bug was found in great numbers under bricks on the banks of Station I. They are not really aquatic but live in damp places.

Order *Decapoda*

Family *Potamobiidae*

Cambarus propinquus

This crayfish is found very frequently both in the swift brick bottomed stream which enters the pond and in the stream which flows into the muskrat region. They bury themselves deep down in the ground about the last of October. Their holes or towers of mud are commonly seen along the banks of the stream. We saw them in the water again as early as March 2d. In May the females bear young upon their swimmerets.

Class *Arachnoidea*

Water spiders were seen frequently swimming on the surface of the water near Station I but none were identified.

Class *Myriapoda*

A single milliped was found at Station I but was not studied.

Class *Insecta*

Order *Ephemeridae*

No May-flies have been found.

Order *Odonata*

Suborder *Anispotera* (dragon flies)

Macromia

The nymph of this form was found on the bottom at the north side of the pond near Station IV.

Libellula pulchella

A nymph of this species was found several times in the aquarium.

Suborder *Zygoptera* (damsel flies)

Lestes nymphs were found among the Elodea of Station IV.

Anomalagrion

A single nymph of this damsel fly was found.

Order *Plecoptera* (stone flies)

A nymph was found under a brick at the incoming stream but was not identified as to genus or species.

Order *Hemiptera*

Suborder *Heteroptera*

This group includes water bugs, skaters, water striders, and water boatmen.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Arthropoda*—Concluded

Family *Corixidae* (water boatmen)

Corixa was found on the surface near the spring at Station II.

Family *Notonectidae*

Notonecta insulata

This backswimmer was very common in the pond near Station II.

Family *Acanthidae*

A small green water strider was very common on the surface of the water both in the pond and in the slow stream at Station V but has not yet been identified.

Family *Gerridae*

Gerris

This long legged skater is quite commonly seen on the surface of the pond as well as in the stream of the muskrat region.

Suborder *Homoptera*

Family *Aphidae*

Rhophalosiphum

This aphid was found on the duckweed near the east side of the pond in the fall.

Order *Lepodoptera*

Land forms were seen on the banks.

Nymphalidae

Euploeinae

Anosia plexippus

The monarch butterfly was found dead on the bank. Larvae were found in May on milkweed. Larvae of viceroy were found on the willow in May also.

Pyrrharctia isabella

The common black and brown caterpillar was seen frequently on the banks.

Order *Coleoptera*

Family *Dytiscidae*

Ditiscus

Larvae of this predaceous diving beetle were abundant. They were found in early March in the mud of the muskrat region. These larvae are commonly known as water tigers.

Family *Hydrophilidae* (water scavenger beetles)

Tropisternus

This is a common black beetle often seen on the surface of the pond.

Family *Haliplidae*

Peltodytes

A small yellow beetle seen frequently on the water near Station II. It is swift in its movements.

Order *Diptera*

Family *Chironomidae*

Chironomous larvae, commonly known as blood worms, were rather common at Station III.

Family *Culicidae*

Mosquitoes were common but none were identified as to species.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Mollusca*

Class *Gastropoda*

Order *Pulmonata*

Physa heterostropha

This was very abundant, especially about the first of April. About the first of April, too, the eggs are found in great abundance in little clusters on the under surfaces of bricks. The snails make definite tracks of mucous which they secrete. These paths may be seen on the surface of the mud at the side of the stream.

Planorbis trivolvis

This snail is frequently seen but not so frequently as is the Physa.

Suborder *Stylommatophora* (land snails)

Agriolimax campestris

This slug was found on the damp earth near the stream of Station III.

Class *Palecypod*

Order *Eulamellibranchiata*

Musculium transversum

This very small delicately shelled bivalve was found in Station III.

Sphaerium

This bivalve was somewhat larger than the above. It was found frequently in the stream leading from the outlet of the pond to the muskrat area.

Phylum *Chordata*

Subphylum *Vertebrata*

Class *Pisces*

Pomoxis annularies, the white crappie, was caught April 8th on the north side of the pond.

Pimephales notatus

The blunt nosed minnow was found the same day in similar situation. These small fish measure 2¼ inches in length.

Micropterus salmoides

The large mouthed black bass was reported as present.

Class *Amphibia*

Family *Bufonidae*

Bufo americanus

A large toad was found on the street car track near Station IV, April 8th.

Family *Ranidae*

Rana pipiens

The common leopard frog was very common in the fall

Hyla pickeringii

The spring peeper was found at Station V and III in March and April. They were very numerous in the middle of May.

Rana catesbiana

A tadpole of this large bullfrog was found at Station V, April 8th.

Class *Reptilia*

No water snakes were found but a water moccasin was reported as being seen. Mud turtles were reported as being found there.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Chordata*—Continued

Class *Reptilia*—Concluded

Order *Ophidia*

Family *Colubridae*

Eutaenia sirtalis

The common garter snake was found in great numbers both in the fall and in the spring. Seven were seen on the bank near Station IV, April 8th.

Heterodoa platyrbinus

The hog nosed snake was found near there September 29th.

Class Aves (Birds)

Order *Anseres*

Anas platyrynchos

Mallard ducks were seen flying over the pond, October 8th.

Chen caerulescens

A man killed twelve blue geese from the region Nov. 11th.

Order *Paludicolae*

Family *Pallidae*

Fulica americana

The American coot, known commonly as the mud hen, was seen very frequently. It was the only representative of the marsh birds seen.

Order *Limicolae* (Shore birds)

Family *Scolopacidae*

Gallinago delicata

The Wilson snipe was seen dead on the tracks Oct. 21st.

Pisobia minutilla

Two least sandpipers were seen March 15th in the muskrat area.

Family *Charadriidae* (Plovers)

Oxyechus vociferus

The killdeer was seen very frequently. It was noticed as early as March 17th and as late in the fall as Oct. 21st. The killdeer is said to feed very largely upon shellfish and larvae from ponds.

Other birds were seen frequently, which undoubtedly affect the life of the pond directly or indirectly.

Order *Coccyges*

Family *Alcedinidae*

Ceryle alcyon

The belted kingfisher was seen as early as March 16th, occasionally diving into the water for small fish.

Order *Pici* (woodpecker)

Family *Picidae*

Dryobates pubescens

The downy woodpecker which stays with us all winter was seen frequently pecking for insect larvae on the giant rag weed stems or other weeds along the bank.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Chordata*—Continued

Order *Pici* (woodpecker)—Concluded

Family *Picidae*—Concluded

Dryobates villosus

The hairy woodpecker, likewise a winter resident, and very much like the downy in appearance except for the larger size, was seen occasionally.

Melanerpes erytrocephabus

The red headed woodpecker, which commonly goes south for the winter, was seen in December and in January this year.

Centurus carolinus

The red bellied woodpecker was seen likewise during the winter months.

Colaptes auratus

The flicker was first noticed March 21st.

Order *Passeres* (perching birds)

Family *Tyrannidae*

Tyrannus tyrannus

The kingbird was seen driving away a crow March 21st.

Sayornis phoebe

This was seen March 21st on a willow tree near the pond.

Family *Corvidae*

Cyanocitta cristata

The blue jay was seen October 21st and December 20th and frequently in the spring.

Corvus brachyrhynchos

Crows were very abundant in the region of the pond.

Family *Icteridae*

Agelaius phoeniceus

Red winged blackbirds were very abundant at the pond in March, April and May. The first one seen was March 17th, but they were seen in the fall as late as November 1st.

Sturnella magna

The meadowlark was seen April 4th and thereafter.

Icterus galbula

The Baltimore oriole was seen May 10th in the woods near Lake Knox.

Quiscalus aeneus

The bronzed grackles were seen in flocks October 8th and were first seen in the spring on March 17th.

Family *Fringillidae*

Astragatinus tristis

The American gold finch was seen in its winter plumage October 2nd. They have little to do with pond life, however, as their food is chiefly weed seeds.

Passer domesticus

The English sparrow is very common.

Zonotrichia guerula

The Harris sparrow was seen in the nearby woods April 9th.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Continued.

Phylum *Chordata*—Continued

Order *Passeres* (perching birds—Concluded

Family *Fringillidae*—Concluded

Spizella passerina

The chipping sparrow was seen in early spring, but the date was not recorded.

Junco byemalis

Slate colored Junco was seen in the willows very frequently throughout the winter months.

Melospiza melodia

The song sparrows were very abundant. They could be seen at all seasons in the willow trees around the lake.

Cardinalis cardinalis

The red cardinal was seen occasionally even in winter months.

Piranga erythromelas

The scarlet tanager, a rare bird, was seen near the lake May 20th.

Iridoprocne bicolor

The tree swallow was seen May 20th on a telephone wire above the bank of the pond.

Seiurus noveboracensis

The water thrush was seen in the brush a little way south of the pond.

Toxostoma rufum

The brown thrasher was seen April 4th.

Dumetella carolinensis

The catbird, which arrives in early April, is seen very frequently in the trees about the pond.

Cerithia familiaris americana

The brown creeper was seen in the winter and again in the spring in the lake region, usually climbing up a tree trunk in search of insect larvae.

Family *Paridae*

Penthestes atricapillus

The black capped chickadee was seen at all seasons of the year.

Sitta carolinensis

The nuthatch was seen several times, usually climbing down a tree trunk head first.

Boeolophus bicolor

The tufted titmouse was seen Feb. 24th and many times thereafter.

Family *Turdidae*

Planesticus migratorius

The robins were very abundant. Feb. 24th nineteen of them were seen immediately south of the pond.

Sialia sialis

The bluebird is one of the first to arrive in the spring. The first ones to be seen, a flock of ten, were seen Feb. 24th.

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GENERAL SURVEY OF THE FAUNA OF LAKE KNOX—Concluded.

Phylum *Chordata*—Concluded

Class *Mammalia*

Order *Glires rhodents*

Family *Muridae*

Subfamily *Microtinae*

Fiber zibethicus

A dead muskrat was seen on the street car track. Muskrat mounds made largely of cat tails are very abundant, and a boy trapping said that he caught thirty muskrats in one day.

Microtus pennsylvanicus

Field mice were seen south of the pond.

Family *Sciuridae*

Arctomys monax

The woodchuck was seen near the ditch just south of the pond Oct. 2.

Family *Leporidae*

Lexus flordianus mearnsi

The prairie cotton tail were very common about the pond.

Man's relations to the life of the pond cannot help being noticed. In the first place the pond is artificial; furthermore it is changed to fit man's needs. In addition to the effect on the pond and its water supply man affects the animals directly. He kills game, the street car runs over animals which live upon animals and plants in the pond. He changes the physical surroundings which affect the life of the animals. Man does much that affects animal life, but still there is a balance.

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A PRELIMINARY REPORT ON THE VERTICAL DISTRIBUTION OF WATER MITES IN GREEN LAKE, WISCONSIN

RUTH MARSHALL, ROCKFORD COLLEGE

While geographical distribution, altitude distribution and distribution according to the character of the bodies of water in which they have been found, have been studied, the vertical distribution of water mites has received little attention. Distribution in the lakes of different elevations has been studied in the Swiss and Scandinavian mountain regions. In this country, little has been done beyond systematic work; data on distribution have been confined almost entirely to horizontal distribution. In this connection, it is interesting to note that Professor F. C. Baker, in his studies on the life in Oneida Lake, New York, records the hydrachnids at varying depths and for different bottoms in a shallow bay.

The author has been fortunate enough to receive from Professor Chauncey Juday, of the Wisconsin Natural History Survey, some collections made at different depths in Green Lake, in eastern Wisconsin. This lake is remarkable among lakes in the glaciated plains regions in its great depth, which reaches 230 feet.

Collections were made in August, 1921, and were in three lots: at depths from the surface to five meters; from five meters to ten meters; and from ten meters to twenty-nine meters. Thirteen genera were represented, most of them common ones. About three hundred and thirty-five individuals were present; the species have not yet been fully determined. As was to be expected, the genera were not found in the same ratios as in ordinary collections made by dragging a cone net through the vegetation of the surface waters, where *Arrhenurus, Piona, Limnesia, Unionicola* and the "red mites", like *Diplodontus*, usually predominate. However, *Limnesia* led in number of individuals and was found at all depths, as were also *Arrhenurus, Neumania* and *Piona*. *Lebertia* and *Torrenticola* were very abundant in the shallow places but were not found at the greater depths. *Mideop-*

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sis occurred only below five meters. The list of the gen era at different depths is given, together with the number of individuals.

A—From the surface to 5 meters.

Arrhenurus manubriator Mar., 10.
Arrhenurus scutulatus Mar., 5.
Arrhenurus fem. unidentified, 16.
Oxus, 1.
Frontipoda americana Mar., 2.
Lebertia, 72.
Torrenticola, 50.
Koenikea concava Wol., 17.
Neumania, 19.
Piona, 13.
Unionicola, 1.
Limnesia, about 50.
Sporadoporus, 11.

B—From 5 meters to 10 meters.

Arrhenurus manubriator Mar., 3.
Arrhenurus scutulatus Mar., 2.
Arrhenurus fem. unidentified, 9.
Koenikea concave Wol., 7.
Mideopsis, 5.
Neumania, 4.
Piona, 5.
Limnesia, 36.
Pionopsis, 1.

From 10 meters to 29 meters.

Arrhenurus americanus Mar., 1.
Mideopsis, 2.
Neumania, 2.
Piona, 1.
Limnesia, 1.

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ADVANTAGES OF RIVER CANYONS FOR ECOLOGICAL STUDY

FRANK THONE, UNIVERSITY OF CHICAGO

The dunes of Lake Michigan have long since become classic soil to American botanists. They were early recognized by taxonomists of a former generation as collecting grounds unsurpassable for richness and variety of flora. Under the eye of Cowles (*1*) they became the cradle of ecology upon this continent, and the starting-point of the whole successional idea. Fuller (*2, 3*), a pioneer in the quantitative study of physical factors of the environment, carried on his work here. And latterly Cowles (*4*) again has made them a point of departure in a significant essay in floristic history.

It is only natural that the dunes should have become a great outdoor laboratory of botany. Their relatively great topographical relief, their restless and rapid changes of position and surface, with erosion and deposition going on simultaneously within radii of a few yards, their relations to significant recent geological events, all conspire to bring together in one place a most remarkable diversity of environmental factors, and therefore also a group of plant communities notable alike for their clean-cut character as ecological associations and as floristic groups.

The botanical advantages they offer, their topographical unity and geographical continuity, and the fact that they have furnished the material for so many well-known pieces of research, have rather tended to make the dunes an overshadowing fact in middle-western botany. It is the object of the present paper to bring out the point that they do not present a unique and isolated phenomenon in an otherwise dull and commonplace stretch of country. Rather they are simply outstanding and critical features in an entity much larger than themselves, an entity that has many other features just as critical though less outstanding, which, nevertheless, await and will reward scientific investigation.

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I do not need to remind this audience that the dominating event in the history of all the botany of this region, whether floristic or ecological, was the advent of the glaciers. Their advance and retreat, and the postulated climatic fluctuations that have occurred since their final disappearance, were the ultimate causes of the distributional peculiarities of floral disjuncts of northern, Appalachian and southwestern affinities, as well as of the successional relationships of the vegetational communities proper to the region. The glaciers set the problems in this part of the country for students of ecology and field botany in general.

Communities of floral disjuncts, as well as the most clean-cut display of successional series, will always be found where the greatest development of topographical and soil diversities give rise to the most marked modifications in ecological factors. These critical points, these points of profitable attack, therefore, must be sought out and studied not as discrete and unrelated matters of interest, but rather as coordinated parts of a whole. The rocky peninsulas and islands of the Superior region, the morainal lakes of Minnesota and Wisconsin, the dunes of Lake Michigan, and that remarkable series of steep-sided river canyons scattered across the upper Mississippi valley from Ohio to the Dakotas, are all chapters in one great work, and all must be read before any may be fully understood.

It is about the river canyons that I want to speak for a few minutes. In advance I want to say that I do not come to tell about them, for I have only begun to try to find out a little about a single one of them; rather I stand as one just a bit aghast at the size of the task and look about for help. It is emphatically more than a one-man job. What I bring is a challenge and an invitation.

These canyons, as I have said, are scattered across nearly the whole of the upper Mississippi valley. Many of them have more than local repute. Sugar Grove in Ohio, Turkey Run in Indiana, Starved Rock and Apple River in Illinois, the Dells in Wisconsin, Wildcat Glen, the Palisades of the Cedar and Steamboat Rock in Iowa, are familiar enough names to most of us, and there are

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plenty of others which, if less well known, are quite as beautiful and striking in their scenery, and quite as interesting in their natural history. In all of them one gets much the same kind of story: a great telescoping of successional series and unusual groups of plants far out of their ordinary range. Each of these places is a "farthest south" in its own region for such northern species as white pine, yew, aspen, Canadian elderberry, harebell and Arctic primrose. Each has outliers of southeastern and southwestern floras. Naturally the eastern forms are more numerous in Ohio and the western forms in Illinois and Iowa, but the significant thing is that in any locality the canyon disjuncts represent a long jump from the nearest open-country community of the same species. Thus, a well-developed stand of sugar maple is a noteworthy feature of the Iowa canyons, while at Sugar Grove, Ohio, where sugar maple is a commonplace, the rhododendron, whose main range is in the southern Alleghenies, becomes a sort of floristic equivalent. There is no point in piling up examples; the character of these canyons as botanical outposts is evident at a glance even to a casual tourist.

The presence of these disjuncts, particularly of the northern ones, becomes very suggestive when the location of the canyons is examined in connection with the line representing the farthest advance of the last (Wisconsin) ice sheet. The accompanying map (fig. 1) shows, in a roughly approximate way, the relation of the half-dozen canyons named in the preceding paragraph to the edge of the Wisconsin drift and also to the driftless "island" in southern Wisconsin and northern Illinois and Iowa. The older drift exposures are omitted for the sake of simplicity; what is shown is sufficient for the purposes of illustration. Moreover, the erosion due to the release of water from this, the latest of the glacial masses, is still fresh, and the sides of the cliffs and canyons are still actively weathering, so that the ecological factors here are more active and more sharply contrasted than they are in parts of the older drift not so immediately affected.

It was on the sides and edges of these canyons that the first hardy tundra vegetation appeared when the last of

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the ice melted under the rain-deluges of its own begetting, back in the earliest post-pleistocene, and here one still finds them: conifers and ericads and reindeer-lichens. It was up the rich and sheltered valleys that the plants of a milder climate came, pawpaws and tulip-trees and sassafras, and it is in the valleys that they have held their place. Where the country rock is a sandstone, as at Starved Rock, the newcomers from the southwest, cactus and sagebrush and bunchgrass, gained and kept a foothold where the soil from its decomposition accumulated. And everywhere one can find places where the whole successional series proper to the region, from the burr oak of the prairie edges and the black oak of the dry upland woods, lie only a literal stone's throw from the elm and linden of the floodplain and the willows at the water's edge.

An excellent illustration of such a place is Lovers' Leap cliff at Starved Rock, shown in figure 2. (A Lovers' Leap is another feature that most of these canyons

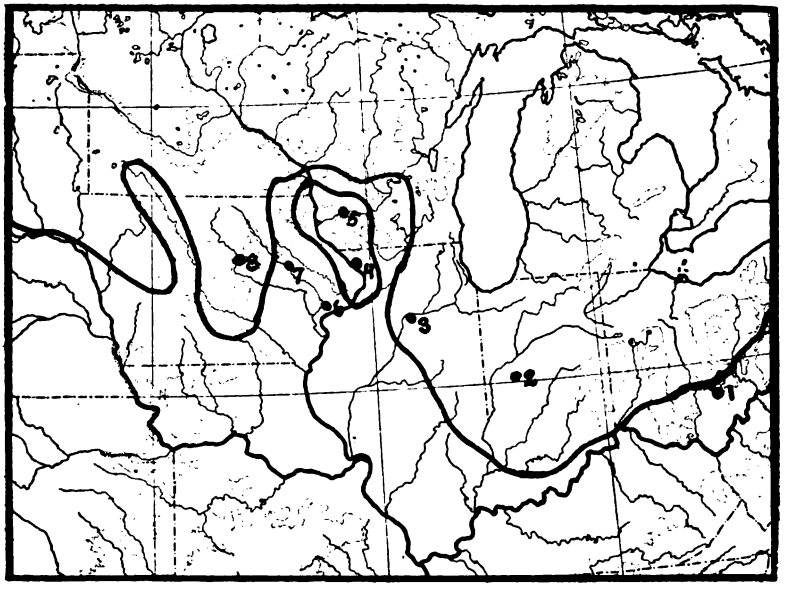

Fig. 1. Map showing distribution of representative river canyons.
1. Sugar Creek region
2. Turkey Run
3. Starved Rock
4. Apple River
5. The Dells of the Wisconsin
6. Wildcat Glen
7. Palisades of the Cedar
8. Steamboat Rock

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have in common.) Here on the thin soil of the plateau is an association of black oak, with a few burr oaks about the margin, and bracken fern and xerophytic herbs under the trees. At the edge of the cliff, and along precarious footholds on its sides, where the steep drop toward the river comes, are white pine, arbor vitae and juniper, with mountain holly, shadbush, blue-berry and huckleberry, harebell, wild lily-of-the-valley and polypody. On the inland slopes, where talus has accumulated against the sides, come red and white oaks and witch-hazel, shading magnificent ferneries and beds of mesophytic spring flowers. At the foot, on the river terrace, is a mixed hardwood growth, ranging from white oak and sugar maple through elm, linden and Kentucky coffee tree to soft maple and willow at the water's edge. On an exposed shoulder of the plateau, where weathered sand has gathered, are bunch grasses, euphorbia and xerophytic composites and legumes. And it all lies within a radius of less than two city blocks. Even the dunes cannot equal this.

All this wealth of botanical possibilities is practically untouched. Griggs (*5*) has worked out the botany of the Sugar Grove region pretty thoroughly. Pepoon (*6*) in 1919 presented a plea before this society for the creation of a state park at Apple River. Cowles (*7*) has a brief section on botany in the bulletin of the Chicago Geographic Society on the Starved Rock state park. There are brief statements, mostly mere paragraphs, by various authors on the Iowa canyons in a report of the Iowa State Board of Conservation (*8*). Aside from some popular articles, that is about all there is in print. During the spring and summer of 1921, at the suggestion of Doctor Cowles, I spent a great deal of time at Starved Rock, but what I have to say is still *im werden,* and I do not feel that my data more than scratch the surface.

When it is recalled that there are dozens of such canyons, big and little, each with its own story to tell and none complete until all are complete, do you wonder that I send up a Macedonian cry for help? Here is botanizing, interesting, profitable, worth while as contributory data in the solution of a problem of continental

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Fig. 2. Lovers' Leap, Starved Rock State Park, Illinois.

Fig. 3. Looking down a side canyon, Starved Rock State Park.

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size. Every one of us is within striking distance of some sort of a river canyon, perhaps in our own home county, certainly within week-end flivvering distance. If there is anyone who is casting about for something promising in field botany, I for one, having made proof of the pudding, can assure him that it is most excellent eating.

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THE ECOLOGY OF RHUS TOXICODENDRON

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It was suggested that more information was needed on the variations in individual species in relation to their environments. Rhus Toxicodendron was selected for study, not because of its poison character, but because it is a species which has a wide distribution, being found, as you know, in all situations from the very dry to the very wet. Field studies were made in eight typical locations during July, August, and September of last year, 1921. Measurements were made from 75 or more leaves in each location, being careful to consider only leaves which were mature and to consider all conditions of the fully developed leaves. From these measurements the average size was calculated. All further study was made from the average leaves. For convenience the lots have been lettered A, B, C, D, E, F, G, H.

When the leaves were arranged in a descending series, beginning with the most mesophytic, it was noticed that they could be divided into four groups. Only one lot of each of the groups will be considered today, by figures B, D, F, and G.

The leaves of lot B are from a moist dune environment, located at Wycliff, Ind. The soil, of course, was sandy. The pocket was quite deep so that the bottom of it must have been near the level of the lake. From the other plants growing in the same location the degree of mesophytism can be seen. The more prominent ones were:

Acer saccharum
Tilia americana
Quercus Alba
Pinus Strobus
Hammamelis
Psedera
Fragaria

The leaves from which measurements were made were growing on the side of a dune very near the bottom in the shade of the maple trees.

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The leaves of lot D are from a flood plain of the Desplaines river at Riverside, Ill. The plot was about fifteen feet from the river and the soil was quite moist. Other species growing in the same situation were:

Quercus macrocarpa
Acer saccharinum
Juglans nigra
Tilia americana
Ulmus americana
Ambrosia trifida
Crataegus
Panicum

The leaves from which measurements were made were growing in the shade of an elm tree.

Lot E was located at the top of a dune at Mineral Springs, Ind., a xerophytic dune environment. The other species in the same environment were:

Juniperus communis
Cornus stolonifera
Rhus aromatica
Vitus vulpina

The plants were growing on bare sand, but were more or less shaded.

Lot G was located on a sandy level beside the tracks at Smith, Ind. The soil, though sandy, had more humus than either of the other dune locations. The other species found there were:

Populus deltoides
Plantago
Fragaria
Salix (nigra)
Grasses
Compositae

The situation seemed very xerophytic and the plants were not as shaded as in the other three locations.

From some of the leaves collected in the different plots, blue prints were made in order to determine the

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areas. The area in square centimeters of the end leaflets from these four representative plots were:

Lot B, 63
Lot D, 36
Lot F, 17
Lot G, 12

These areas, as you see, conform with the types of their environments.

This has not proven true for the thickness of the leaves. When sections were made and measured, there seemed to be almost no relation between xerophytism and the thickness of the leaf. In the diagram, the leaf sections were arranged in the same order as the leaf areas in the preceding diagram. As you can see, the mesophytic leaves may be as thick as the xerophytic, or even thicker in some instances.

The last and most important contrast is in the microscopic study of the sections. Though it seems impossible to tell by the thickness of the leaves whether they are mesophytic or xerophytic—when the general compactness of the tissue is considered, the difference is very striking. Cross sections were drawn on graph paper in order to determine the relation between the total area of the leaf section and the part of that area occupied by cells. In this way a coefficient of compactness could be determined. This work is not yet finished and I am not ready to give a conclusive statement, but so far as this has been considered the coefficient of compactness is:

Lot B, 61
Lot D, 74
Lot F, 87
Lot G, 89

This conforms with the leaf area and type of environment.

Considering the individual elements, as seen in the cross section of the leaf, the greatest variation is in the upper epidermis and the spongy tissue. The variations in the upper epidermis are marked, the epidermis being much thicker when the leaves were growing in xerophytic regions. Some species of plants have variation in the number of the rows of palisade cells when growing in

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different environments. In the case of Rhus Toxicodendron there is not this contrast. In almost no case is there more than one layer of palisade cells. Nor is there any marked difference in the thickness of the one layer of cells. In the spongy tissue there is variation, not in the thickness, but in the restriction of the amount of air spaces. This, of course, is what causes the variation in the coefficient of compactness.

In conclusion, The variations in the structure of the leaves may be summed up in the following:

1. The leaves are greater in area where the situation is mesophytic and smaller in the xerophytic locations.

2. There is no apparent agreement in the relation between leaf area and leaf thickness. This is contrary to the usual condition.

3. There is agreement between the compactness of the leaf and its environment.

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THE EARLY DEVELOPMENT OF THE VERTEBRAL COLUMN OF THE ALLIGATOR.

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This study upon the early development of the vertebral column in the alligator was made upon the collection of vertebrate embryos in the zoological laboratories of the University of Illinois. Successive stages of young alligators, ranging in length from 6 mm. to 30 mm., were sectioned transversely; and the attempt was made to determine the origin of those mesodermal elements which contribute toward the formation of the vertebra, as well as their subsequent relation to each other in this formation. Reconstructions in wax have been made of the developing vertebra in the caudal, sacral, lumbar and thoracic regions of the various stages; so that careful comparisons could be made within these areas. This preliminary report will concern itself with the earlier differentiation only, and the more complete discussion will follow in a later paper.

In an embryo 6 mm. long, the entire skeletal support rests in the notochord, a fibrous rod-like structure which lies ventral and parallel to the central nervous system. At this stage those cells which comprise the chorda are already migrating toward the periphery, so that a more or less indefinite epitheliomorph layer may now be identified (Fig. 1.) As a result of this migration, large vacuoles have appeared within the chorda, some of which measure fully one-third the diameter of the notochord itself. Immediately external to the epitheliomorph layer is a rather prominent deeply stained notochordal sheath, which, in the alligator, is not differentiated into two layers as is true for the Elasmobranchs and Ichthyopsida in general. In these embryos this sheath is a relatively thin layer, and under a magnification of 700 diameters it presents a fibrous appearance. It would further appear that this notochordal sheath is probably not a product of the tissue external to the chorda; but that it may arise from those cells within the notochord itself, and possibly as a secretion from the epitheliomorph layer.

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Those cells, which are potentially scleroblastic and later contribute toward the development of the membranous vertebrae, are derivatives of the median wall of the lateral myotomes, which lie between the spinal cord and the external body wall. Unfortunately, I have been unable to secure any sufficiently early stages which show the migration of these scleroblastic cells; but, following Schauinsland (1906) in his study of the very early stages in the development of the vertebral column of Sphenodon, the Australian lizard, it would appear that all of the cells of the lower half of the medial plate of each myotome are potentially scleroblastic. During the process of the migration these cells come to be arranged into very definite groups which occupy characteristic positions along the notochord and the spinal cord (Fig. 2.)

In the earliest embryo of my series, these groups or masses of scleroblastic cells are definitely located in positions along the dorso-lateral and ventro-lateral margins of the notochord. These groups may be readily recognized by the large size of their constituent cells and likewise of their nuclei, as well as by the deeply staining quality of the cytoplasm. It is quite possible, in this stage, to recognize eight such cell groups within each body segment, all of which are concerned in the development of the definitive membranous vertebra. Of these vertebral elements, four lie upon each side of the notochord, two in the angle between the notochord and the spinal cord and two along the latero-ventral margin of the chorda. (Fig. 3.)

Since the segmental blood vessels, which course upward from the dorsal aorta within the dissepiments between successive somites, afford an excellent means for the identification of the limits of each body segment, it is possible to designate these eight vertebral elements by such terms as characterize their position in the segment. Accordingly, upon that basis, those elements which lie more anterior in each segment may be designated as cranial and those most posterior as caudal. Furthermore that element which is cranial and lies along the upper margin of the notochord may be called a

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cranineural; while the more ventral one, because of its association with the blood vessels, would be known as a cranihaemal element. On the same basis, then, the more posterior of these elements in each segment would be designated as the caudineural or the caudihaemal depending upon its dorsal or its ventral position. These terms were suggested by Professor J. S. Kingsley, with whom the writer frequently conferred during the investigation. Thus it is evident that each body segment would be characterized by a pair of cranineurals, a pair of cranihaemals, a pair of caudineurals and a pair of caudihaemals. This method of identification is entirely satisfactory, because it not only affords an accurate determination of the position of each element, but it also does away with the use of such terms as pleurocentrum, hypocentrum and arcualia, the homologies of which are so uncertain.

In addition to the segmental blood vessels which mark the limits of body segments, each cranineural and caudineural bears a very definite relation to the nerve roots of the spinal nerve. Passing backward through a segment, the order of sequence in the position of these parts is as follows. Just posterior to the segmental blood vessel is the ventral nerve root; this is followed by the cranineural, the ganglion of the dorsal root, the caudineural, and the next succeeding segmental blood vessel, each in the order indicated. The cranihaemal and the caudihaemal of each segment lie along the ventro-lateral margin of the notochord, but in approximately the same plane as do the corresponding neural elements. (Fig. 3.)

Schauinsland (1906) in his description of the development of the vertebral column of Sphenodon, describes the single sclerotome or mass of scleroblastic cells upon each side of a body segment. Subsequently, by means of sagittal and frontal sections, he was able to demonstrate a transverse cleft in each sclerotome; so that the terms cranial half-sclerotome and caudal half-sclerotome were employed to designate the resulting parts. Unfortunately, in this study, frontal and sagittal sections were not available, and such transverse clefts as Schauinsland describes were not identified in my material.

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Immediately following the formation of the eight vertebral elements there occurred a fusion of the two cranial elements upon each side, as well as of the two caudal elements. In each case cells of the cranineurals and caudineurals grow ventrally to meet the cells of the cranihaemals and caudihaemals; so that as a result four vertebral components may now be identified within each segment. Partially following the terminology of Schauinsland, the term cranial part-sclerotome is employed to designate the fused cranineural and cranihaemal component; while the term caudal part-sclerotome likewise identifies the fused caudineural and caudihaemal component. Since the caudal vertebral component in each case is considerably larger than the cranial, the term part-sclerotome seems more adequate in its designation than the term half-sclerotome of authors.

Following the fusion of the original vertebral elements to form part-sclerotomes, as above described, there occurs a subsequent fusion of these part-sclerotomes to form entire sclerotomes within which the definitive membranous vertebra will later arise. The fusion of these part-sclerotomes is affected as follows. The caudal part-sclerotome, considerably larger than the cranial, extends somewhat dorsalwards, and reaching more posteriorly comes to unite with the smaller cranial part-sclerotome of the next posterior segment. Thus it is evident that entire sclerotomes are formed, not by the fusion of part-sclerotomes within a segment but rather by a fusion of part-sclerotomes of adjacent segments. So that sclerotomes come to alternate in their position with the myotomes from which the trunk musculature is to arise; affecting thereby the alternate relations of vertebrae and muscles in the adult condition. Dorsally these sclerotomes extend to the level of the spinal ganglia, while ventrally each reaches downward a very short distance from the notochord. (Fig. 4.)

In an embryo 7 mm. long, three parts of the above described sclerotome may be identified. The upper more narrow portion, which lies adjacent to the spinal cord, is clearly the first stage in the development of the membranous neural arch. Likewise, the lower or haemal por-

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tion is as clearly the beginning of the membranous haemal arch; while the larger intermediate area, a probable derivative of the original cranial element, will contribute largely toward the primary centrum of the vertebra. At this stage, also, a rapid cell proliferation has occurred between the bases of the haemal processes along the ventral surface of the notochord and form a series of hypochordal bars which are to form the lower portions of the primary centra. (Fig. 5.)

It is very evident that the scleroblastic cells comprising the sclerotome are clearly of two kinds. Those cells which compose the areas of the developing neural and haemal arches are spherical and contain very large and deeply stained nuclei; while those of the primary centrum as well as those cells which comprise the hypochordal bar are strikingly oval or spindle-shaped and are more closely applied to each other. As yet the scleroblastic cells do not appear in the area between the notochord and the spinal cord, so that the primary centrum is incomplete in that region. Since the primary centrum in the alligator is formed entirely external to the notochordal sheath, a considerable contrast exists between that condition which maintains within the Elasmobranch fishes and certain other Chordates. In these latter groups, openings occur in the notochordal sheath, through which the scleroblastic cells may enter the chorda and form the primary centrum within it. But in the alligator, at this stage, these centra appear as a series of membranous rings, incomplete dorsally, which lie just external to the notochordal sheath and in the same transverse plane as do the neural and haemal membranous processes. These centra are separated from each other by wide spaces, into which scleroblastic cells will later migrate and which will subsequently be known as the intercentra; so that the notochord presents at this time a very characteristic moniliform appearance.

These sclerotomes, together with the hypochordal bar, constitute the beginning of a membranous vertebra. (Fig. 6.) At first, in all the regions of the body, the lower or haemal processes lie in approximately the same transverse plane as do the neural processes; but in the

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sacral and the caudal regions, it would appear, however, as though the haemal process had shifted toward the anterior margin of the segment. As a result, in these posterior regions, this ventral part of the sclerotome lies just posterior to the segmental blood vessel and adjacent to the ventral root of the spinal nerve. In this stage these haemal processes are more elongate in the tail where they extend ventrally to a position lateral to the caudal artery and vein. In the region of the trunk and thorax, however, they are greatly reduced and appear only as mere rudiments; while in the neck, there is no evidence whatsoever of any haemal process.

In an embryo 10 mm. long, a further migration of the constituent cells of the notochord has taken place, so that a clearly defined epitheliomorph layer is produced. As a result the vacuoles are relatively larger than before. The notochordal sheath is relatively thicker than before, and under higher magnification its fibrous composition is more evident.

A marked increase in the relative thickness of the primary centrum is apparent at this stage. Differentiation of the cells has resulted in the formation of two distinct layers, the inner one of which lies just external to the notochordal sheath. This inner layer is composed of the long spindle-shaped cells which characterized the earlier primary centrum, and it extends entirely around the chorda connecting the bases of the neural arch processes beneath the spinal cord. The outer relatively thinner layer is composed of larger spherical scleroblastic cells similar to those of the earlier part-sclerotome; and they are evidently a product of these part-sclerotomes together with additional cells from the original myotomes.

In addition to these primary centra, primary intercentra may now be identified. Cells, which comprise the latter, have apparently arisen from the original sclerotomes, and have migrated anteriorly and posteriorly along the notochord, forming a series of intercentra which alternate with the successive primary centra. These intercentra, which lie opposite the original somatic myotomes, differ from the centra in the absence of

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the inner layer; but are composed entirely of the larger spherical cells.

By a further proliferation of the cells of the membranous neural arches, the origin of which occurred in the earlier stage, and by a further addition of cells from the myotome, the entire spinal cord is at this 10 mm. stage covered dorsally and laterally by a continuous membranous structure. Openings, of course, occur for the exit of the spinal nerve roots and for the inclusion of the dorsal ganglion within each segment. This structure, although continuous, is much thinner in the intervertebral regions, since the cartilaginous vertebrae are to arise in the position of the original sclerotomes.

The first appearance of a cartilage vertebra may be identified in this same 10 mm. embryo. In the approximate position of the original caudal part-sclerotomes of the trunk region, the cells of the membranous sclerotome have transformed into a procartilage neural arch which rests upon the inner layer of the primary centrum. This procartilage neural arch extends dorsally and slightly posteriorly, and terminates just back of the upper margin of the dorsal ganglion. The lower or haemal arches appear as mere stumps in the trunk region, but in the tail these structures are much longer than before and nearly encircle the caudal blood vessels. However in neither region is there any evidence of a procartilage formation within these lower processes. Nor has such a transformation yet occurred within the primary centrum. So that the vertebral column of a 10 mm. alligator may be said to be composed of a series of independent procartilage neural arch processes which rest upon the membranous primary centrum and lie along the lateral aspect of the spinal cord.

A further consideration of the later development of the column will appear in a subsequent paper.

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EXPLANATION OF PLATE.

Fig. 1. Cross section of a notochord of an alligator embryo, 6 mm. long.

Fig. 2. Diagrammatic sketch of the myotomes in the trunk region of a 6 mm. embryo, showing the origin of the scleroblastic cells.

Fig. 3. Side view of the notochord and the spinal cord of a young alligator, showing the position and arrangement of the vertebral components.

Fig. 4. A single pair of sclerotomes, which show their position and their relation to the notochord and the spinal cord.

Fig. 5. A ventral view of the notochord, showing the series of hypochordal bars in the trunk region.

Fig. 6. Neural arch and haemal arch formation, and their connection with the hypochordal bar.

cah	caudihaemal	na	neural arch
can	caudineural	ns	notochordal sheath
crh	cranihaemal	s	sclerotome
crn	cranineural	sb	scleroblastic cells
dt	dermatome	sbv	segmental blood vessel
el	epitheliomorph layer	sc	spinal cord
ha	haemal arch	sg	spinal ganglion
hb	hypochordal bar	v	vacuole
mp	muscle plate	vn	ventral nerve root
n	notochord		

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PLATE

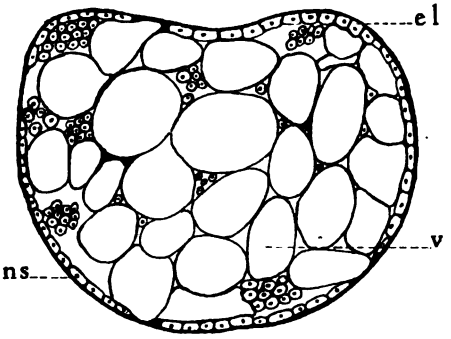
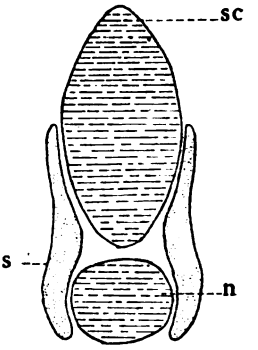


fig 1



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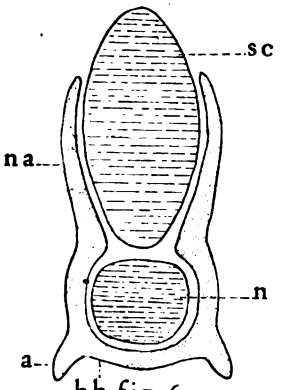

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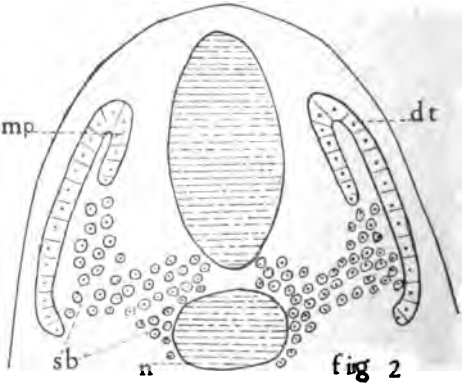

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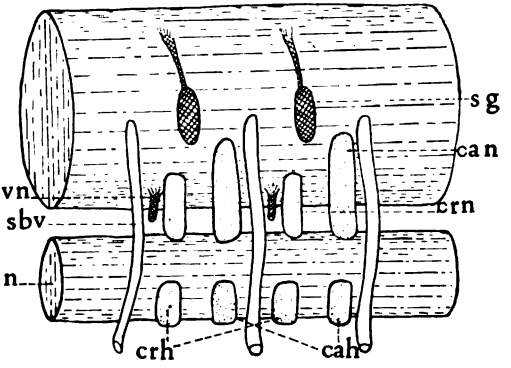

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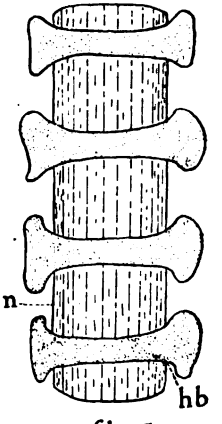

fig 5

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PAPERS ON CHEMISTRY AND PHYSICS

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PREPARATIONS OF THE METALS OF THE RARE EARTH GROUP

H. C. KREMERS, UNIVERSITY OF ILLINOIS

The extreme electropositive character of the rare earths renders the preparation of the metals a difficult one. Their isolation is rendered still more difficult by the fact that the separation of the individual members from each other is no mean task. The rare earth ores are fairly abundant, especially those in which the cerium group predominates. In fact, in the incandescent mantle industry thousands of tons of cerium group material are annually thrown away after the extraction of thorium from monazite sand. This enormous waste of rare earth material has been a great stimulus for research on the preparation of the metals.

There are in general two methods of attack in the isolation of the metals: Reduction chemically by metals more electropositive in character and electrolysis of fused salts.

The only metals which have been used more or less successfully for reduction chemically are sodium and potassium. The method has been partially successful and that only in the case of the less positive of the rare earths, namely the yttrium group. The method usually used[1] was to mix the anhydrous chloride of the rare earths with the equivalent amount of granulated sodium, placing the mixture in an iron or nickel boat in an iron tube and allowing the reaction to take place under a high vacuum. The metal obtained as a fine powder is lixiviated with a large amount of water to dissolve away the sodium chloride, undecomposed chlorides and unused sodium. The metal powder can then be fused into a coherent state in a vacuum furnace. This method would, of course, hardly be applicable in a commercial way since it would be far too expensive and slow, but it has been the means of making a study of some of the physical and chemical properties of the rare earth metals. Perhaps the greatest drawback to the method is the fact that the

1. Hicks. Jour. Am. Chem. Soc. *40*, 1619.

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reaction of sodium and a rare earth chloride is a reversible one, and that metallic sodium can very easily be prepared by the interaction of a rare earth metal and sodium chloride.

Electrolysis of the fused salts of the rare earths has been in commercial use for several years. This has, of course, only been applied to the production of cerium group metal or "misch metal". Séveral tons of misch metal have been made annually in this country alone during the late war. Considerable use of this metal was made in igniters for hand grenades, tracer bullets and trench lighters. The raw material in the production of misch metal has always been the double sodium cerium group sulfates obtained as a by-product in the incandescent mantle processes. The waste liquors after the extraction of Thorium are simply acidified with sulfuric acid, and upon the addition of NaCl the double sodium cerium group sulfates will precipitate out. The double sulfates are then converted to the rare earth hydroxides by treatment with strong hot sodium hydroxide solution and the soluble sodium salts filtered off. The hydroxides are then converted to neutral chlorides, filtered to remove any rare earth phosphates that may have formed and dehydrated. The anhydrous chlorides are electrolized, using a cast iron pot as cathode and a graphite rod as anode. The melting point of the bath is usually sufficiently high to melt the misch metal as fast as it is formed. The melting point of misch metal is about 750°C, well below that of the melting point of the anhydrous chloride, the latter being about 950°C. It is thus evident that in the electrolysis of the fused chlorides of the cerium group or in general any of its members, the melting point of the metal being below or near that of its anhydrous chloride, the metal is easily obtained in a coherent state. Excessively high temperatures of the bath are not necessary and there is very little volatilization of the latter. Considerable interest has been shown in the use of misch metal as a deoxidizer for cast iron,[1] steel and other alloys requiring a scavenger to clean the

1. Maldenke. Iron Age *105*, 324 (1920).

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molten metal of its dissolved oxygen. Misch metal has properties which make it quite desirable for this purpose: melting point 750°C, heat of oxidation 1740 calories per gram, and alloys with most metals are readily formed.

With respect to the yttrium group, considerably more difficulty is encountered in the isolation of the mixed metal or any of its individual members. The metals are less electropositive, it is true, but their melting points are very much higher. Yttrium is reported as melting at 1250° C, Erbium 1250° C and ytterbium as high as 1800° C, although there is some doubt with respect to the last named. These high melting points are not the greatest evil to be overcome. Most of the anhydrous chlorides of the yttrium group have low melting points as compared with those of the cerium group. Yttrium chloride melts at 680° C, dysprosium chloride at 700° C, and ytterbium chloride at 880° C. Thus in the electrolysis of the fused chlorides of this group it is impossible to obtain the metal in the fused state, and since the temperature of the bath must be maintained in the neighborhood of 1000° C there is a large loss of salt due to volatilization. It has been found that yttrium chloride is quite volatile slightly above its melting point.

Since the metals of the yttrium group are less electropositive than the cerium group and are also slightly less positive than aluminium, it has been possible to prepare the mixed metals of this group by a solution of the oxides in a molten bath of cryolite and subjecting them to electrolysis similar to that of the production of aluminum.[2] It is also possible to use the double fluorides of the yttrium group instead of the cryolite. By these methods there is very little loss of any material due to volatilization.

It is quite probable that most of the rare earth metals as individuals will not command a great commercial use since the isolation of their salts is a very difficult matter.

2. Hicks. Loc. cit.

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In summation then there are perhaps four metals of the rare earths which will find commercial use:

Cerium, which can be separated from the cerium group with considerable ease and has already been prepared and exhaustively studied.[1]

Cerium free misch metal, for which a demand will be created in time. The element cerium having two stages of oxidation is at times undesirable as a metal, and cerium free misch metal would meet this difficulty.

Cerium group metal, or misch metal which has found considerable use in pyphoric alloys as deoxidizers.

Yttrium group metal, slightly less electropositive in character but having a much higher melting point.

1. Hirsch. Trans. Am. Elec. Soc. 22, 57.

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CONCENTRATION OF RADIUM FROM CARNOTITE ORES

B. S. Hopkins and G. C. Ruhle, University of Illinois

Carnotite is a potassium uranyl vanadate of essentially the composition represented by the formula $K_2O.2UO_3.V_2O_5.8\ H_2O$. All the mineral substances present are valuable, but the most valuable component, radium, is present in such a small proportion that it cannot be shown readily in the formula. It requires a ton of relatively rich carnotite ore to produce 10 milligrams of radium. It is very evident then that any method which is efficient in the removal of radium must be capable of effecting practically 100 per cent extraction. It is also clear that a very important part in the process will consist in the concentration of the minute quantities of radium after they have been removed from the great bulk of the ore.

For the first step in the process, the United States Bureau of Mines recommends the employment of nitric acid, by the use of which practically all the radium together with most of the other valuable mineral constituents present is converted to the soluble form. The solution obtained in this manner is nearly neutralized, barium chloride is added, and the radium and barium are precipitated by adding sulfuric acid. The precipitated radium—barium sulfate is filtered off, and from the clean solution uranium is precipitated, usually as sodium uranate and the vanadium either as ferrous vandate or calcium vanadate.

The main advantage claimed for this process is the high recovery of radium. The disadvantages arise from the cost of nitric acid and the fact that there is only partial extraction of vanadium. In large measure the cost difficulty is overcome by the fact that a very considerable portion of the nitric acid may be recovered and used again. If the main object in view is the extraction of radium, this method is said to be especially efficient.

The radium-barium sulfate, which contains only a very small per cent of radium, must now be subjected to treatment for the concentration of radium. The usual pro-

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cedure is as follows: The mixed sulfates are reduced to sulfides by heating with charcoal or are converted to the carbonates by boiling with sodium carbonate solution. The sulfides or carbonates so obtained are dissolved in hydrochloric acid and the resulting solutions subjected to fractional crystallization. This method of concentration depends upon the fact that when a saturated solution of radium-barium chloride is cooled from 100° to 0° the crystals formed are much richer in radium than the original solution. Accordingly, if a solution of the mixed chlorides is evaporated until there remains not quite enough solvent to keep all the salts in solution, there will be a tendency for the radium chloride to crystallize out, while the mother liquor will become correspondingly richer in barium chloride. After this process has been repeated many times, it is found that the radium is nearly all concentrated in the crystal fractions, while the solutions at the "soluble end" of the series contain no radium. It has been found that the concentration of radium takes place more rapidly if this process of fractional crystallization is carried out by the use of bromides in place of chlorides. This is explained by the fact that the bromides are more soluble than the chlorides. If a saturated solution of the chlorides is cooled from 100° to 0°, about 50 per cent of the solute crystallizes out; but under the same conditions the bromide solution will give up only about 34 per cent of the salts. Hence, there is a more rapid concentration of the radium if this salt is used.

The concentration of the radium in any fraction may be calculated from the equation:

$$C = AK^n$$

in which ^{n} is the number of crystallizations, A is either the actual or assumed concentration of some dish to start with, and K, called the enrichment factor, is a constant when the crystallizations are carried out under exactly similar conditions. It represents the relative concentration of the radium in the crystals to that in the original material. It has been shown[1] that the enrichment factor is practically independent of the degree of

1. John L. Niermann. Jour. Phys. Chem. 24, 192 (1920).

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acidity of the mother liquor; likewise[2] that this factor for a bromide system is 2.6 while for a chloride system it is about 1.6. Reasoning from the familiar relationships shown in the periodic table, it might readily be concluded that if a bromide system was more efficient than a chloride system the fractional crystallization of the iodides would be considerably more efficient than either the chloride or the bromide. With this view point in mind a series of experiments are now being conducted to determine the practicability of an iodide system of radium concentration.

Before this experiment could be carried out successfully, it was necessary to determine the best method of preparing the iodide solution. Several methods were tried such as: (1) Superheated steam was passed over the sulfide, converting it to the hydroxide, which was then heated to a dull red in a stream of hydriodic acid gas; (2) the sulfide was transformed to the iodide by boiling with an alcoholic solution of iodine; (3) the sulfide was added to a boiling solution which contained slghtly more than the calculated amount of ferrous iodide; (5) the sulfide was boiled with hydriodic acid solution and a small amount of iodine in hydriodic acid was added. Of these methods, the last proved to be the most satisfactory, so it was employed.

To test out the efficiency of the halide fractionation system, three samples of radium-barium sulfate, each weighing 100 grams, were reduced with charcoal and the resulting sulfides were treated with hydrochloric, hydrobromic and hydriodic acids respectively. After the action had ceased they were boiled to expel hydrogen sulfide, filtered and the residue washed thoroly. The filtrates were evaporated to dryness, taken up with a small quantity of water to which was added a little of the free acid, and the fractional crystallization begun, by evaporating on a steam bath until the solutions were completely saturated. Then the dishes were cooled in ice water, the crystals filtered out, redissolved in pure water and recrystallized.

2. C. E. Scholl. Jour. Am. Chem. Soc. 42, 889 (1920).

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To test the efficiency of the solvent action of the three halogen acids, the residues from the acid extractions were analyzed for their barium content and were found to contain practically the same per cent of that element. Hence, it was concluded that the acid extraction was the same in all cases and that the three solutions presumably contained the same amount of radium.

After several crystallizations of the three halide systems, equivalent amounts of the richest fraction of each were placed in the case of a charged electroscope and the time of discharge noted. The iodide discharged the electroscope more quickly than either the chloride or the bromide, but the work has not yet progressed to the point which will permit a definite statement concerning the value of its enrichment factor. Another decided advantage in the use of the iodide comes from the greater solubility of this salt over the others; hence a given amount of radium in the iodide solution occupies a much smaller volume than it does in the chloride or bromide solution. This permits the use of smaller crystallizing dishes, a material saving on a large scale operation.

The use of the iodide for radium concentration would not be practical unless it were possible to recover a large per cent of the iodine at the end of the process. Accordingly, when the radium had been practically all removed from certain fractions, the barium iodide solutions were saturated with chlorine. The displaced iodine was filtered off, dried and resublimed. The barium chloride solution was evaporated and the crystals were used in the precipitation of the next batch of radium-barium sulfate. The iodine was mixed with a little less than the theoretical amount of red phosphorus, and water was slowly dropped over the mixture. In this manner hydriodic acid was obtained, which was also used in the next series. The recovery was satisfactory, indicating that the operating cost for iodine would be quite reasonable.

Urbana, Illinois, April 25, 1922.

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EFFECT OF X-RAYS ON THE RESISTANCE OF TIN FOIL

W. H. Sanders and C. J. Lapp, University of Illinois

Some unexpected results have been obtained recently in an experiment on the action of X-rays on a beam of electrons. In connection with this the question arose whether X-rays would affect the resistance of a metallic conductor.

The first work in this field was reported by J. W. Giltay[1] in 1896. Because of the similarity between X-rays and light he anticipated that the resistance of selenium would be altered by exposure to X-rays. Experiments confirmed the prediction. Later work has been carried to such point that this property may be applied to measurement of the intensity and of the constancy of X-rays. Giltay mentioned an incidental test on a tin bolometer which gave no indication of a change in resistance caused by the X-rays.

Selenium exhibits a change in resistance also when exposed to the action of radium and radium compounds. At first it might be supposed that the change manifested is caused by the gamma rays. However, experiments carried out by F. C. Brown and Joel Stebbins[2] indicate that the change observed is the result of bombardment of alpha and, particularly, beta particles, the gamma rays having little or no effect. The action of radium bromide on a bismuth spiral was studied by R. Paillot,[3] who reported his work in 1904. He found a change in resistance of about one part in three thousand. The description of his experimental arrangement indicates that alpha particles could not have participated in the action, but no effort was made to isolate the effects of the beta particles or the gamma rays and the work was not followed up.

In view of the lack of quantitative data on any material except selenium and the theoretical importance which a positive result would have, it was thought advisable to

1. J. W. Giltay, Nature, V. 54, p. 109, (1896).
2. Brown and Stebbins, Phys. Rev., V. 25, p. 505 (1907); V. 26, p. 273 (1908).
3. R. Paillot, Comptes Rendus, Vol. 138, p. 139 (1904).

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determine with considerable care whether an X-ray beam has any effect on the resistance of an ordinary metallic conductor. As tin foil was most convenient it was chosen for a preliminary experiment.

The foil was cut into the form of a grid so as to have a total resistance of about 13.1 ohms, not including heavy leads soldered to it. This grid was mounted with shellac on a glass plate and enclosed in a light pasteboard box for the sake of protection from air currents and rapid temperature changes. The grid was placed in a position about twenty centimeters from the target of a Coolidge tube. The current for the tube was furnished by a large Klingelfuss induction coil with a Wehnelt interrupter. The equivalent spark gap was approximately six inches.

The resistance measurements were made with a Wheatstone bridge circuit arranged so as to be especially convenient for the detection and measurement of small changes in resistance, essentially a bolometer. The slide wire was shunted and also resistances were inserted at each end so that its equivalent length was about fifteen hundred meters. The galvanometer was a special Leeds and Northup instrument of high sensitivity and low resistance. The bridge arms were so proportioned that the galvanometer was critically damped. The use of a good telescope and a scale three meters from the mirror aided in securing high sensitivity.

The sensitiveness of the arrangement could be determined in two ways, by the deflection resulting from a given shift in the balance point and by the deflection produced when a known change of resistance occurred in the X-branch. As it was more convenient and more accurate, the latter method was employed. In series with the tin foil grid was placed a one ohm resistance which could be shunted by a resistance of ten thousand ohms. The resulting change in the resistance of the X-branch was very nearly one ten thousandth of an ohm. It produced a change of twelve millimeters in the galvanometer deflection. For resistance changes up to at least three thousandths of an ohm there was a linear relation between the resistance increment and the corresponding galvanometer deflection. During all measurements the galvano-

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meter and the battery circuits were closed continuously so that trouble with thermoelectric effects was eliminated.

Under ordinary circumstances the galvanometer deflection exhibited a steady shift resulting from a gradual change in the X-resistance caused by its change in temperature. By reading the deflection at intervals of, for instance, fifteen seconds with the X-ray beam alternately on and off, the effect of the X-rays themselves could be isolated. The results may well be shown graphically, plotting times as abscissa and deflections as ordinate. When temperature changes are occurring, the points will lie on a smooth curve having a positive slope. If a resistance change is produced by the radiation, alternate points will be displaced vertically from the curve by a constant amount. The amount of this displacement gives a measure of the resistance change.

Some difficulty was experienced at first with leakage from the high tension circuit of the Coolidge tube. The amount of interference seemed to be dependent on the frequency of interruption of this current. Proper precautions, however, made this trouble negligible. Several series of observations were made in the manner described. The frequency of the X-rays was varied through a considerable range. Sensitivity tests before and after the measurements showed that a resistance change of one ten-thousandth ohm in the X-branch would cause a deflection of twelve millimeters. No change in resistance caused by the X-ray beam was detected.

Fluctuations in the rate of change of temperature made it impossible to take full advantage of the accuracy of which the bridge used is capable. However it may be said that any resistance change which does occur when tin is subjected to such an X-ray beam is less than one part in four hundred thousand, or less than 0.00025%.

Experiments with more adequate temperature control to permit much greater accuracy and with other elements than tin are anticipated.

In conclusion, we wish to thank Professor A. P. Carman for the facilities of the department.

Laboratory of Physics
University of Illinois
April, 1922.

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INDUSTRIAL CHEMICAL RESEARCH

JOHN C. HESSLER, KNOX COLLEGE

The writer has no thought of entering upon an extended exposition of industrial research, nor upon a description of any special problem, but to give in a few words his impressions of the work done at the Mellon Institute of the University of Pittsburgh, in the hope that these impressions may be, to some of those present, of at least a passing interest.

The Mellon Institute represents, in cement and stone, the ideas and ideals of Dr. Robert Kennedy Duncan. Dr. Duncan, as most of you know, was a pioneer in the popularizing of science, especially chemical science, with the industrialists of America. He was a man of wonderful imagination and of magnetic personality; when he entered a room, he became at once its center; when he spoke, the captains of industry listened. His voice is still heard in the Institute he founded. It was Dr. Duncan's idea that the manufacturer was entitled to the service of men of approved ability, and that the investigator, on the other hand, was entitled to the stimulus and aid which come from companionship with other investigators and the oversight and direction of trained scientific administrators. These advantages the Institute affords.

At the Mellon Institute an industrialist, a company, or an association of manufacturers may become the donor of a fellowship. The conditions are essentially the signing of an agreement stating the relation of the donor, the Institute, and the Fellow, and the contribution of a foundation sum for a period of not less than one year. This sum must be large enough to permit of the purchase of all necessary special equipment and to pay the salary of the Fellow. The Institute gives the Fellow the room for his work, the use of permanent equipment and library, and the direction of the administrative officers. All results obtained during the course of such a fellowship belong exclusively to the donor. One can get some idea of the scope of the Institute's work when he learns that during the year 1920-1921, the foundation sums of

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the Industrial Fellowships totaled $320,848, and that there were 48 fellowships and 83 Fellows. During the ten years ending March 1st, 1921, the total contributed amounted to upwards of $1,500,000; while the overhead expenses of the Institute were approximately $470,000.

To come now to the individual fellowships. The writer recalls very vividly the case of a prospective donor who was being conducted through the building, and who exclaimed, upon entering the room of the Laundry Fellowship: "What on earth has a laundry to do with Chemistry?" Of such stuff are many donors, before they are converted. It happened that the Laundry Fellowship was working upon matters that involved a great deal of Chemistry; not only the routine analyses of soaps, water softeners, water samples, blues, sours, bleaches, and the like, and in the investigation of claims for damage, but also the greater problem of interesting the public in the idea of "sending it all to the laundry", a problem involving not only the renewing of soiled fabrics, but a study of all the complex operations concerned with the weaving, dyeing, and composition of fabrics. The new problem of the laundry is something more than the washing of the collars and "biled" shirt of the bachelor until he gets a wife. The Laundry Fellowship is an association fellowship, with about 1800 members behind it.

Other fellowships bear the names of Synthetic Resins, Bread, Zirconium, Fish Products, Fuel, Plastics, Soap, Enameling, Synthetic Acids, Food Container, Protected Metals, Stove, Sulphur, Oil Shale, Nickel, Flotation, Glass, Oil, Quartz, Gas, Tar Products, Emulsion Flavors, Inks, Cements, Fiber, Yeast, Silicate, Magnesia Insulation, Coke, Organic Syntheses, Insecticides, Glue, Fertilizer, Dental Products, Cleaning, Refractories, Asbestos, Fruit Beverages, and Magnesia Products.

The Bread Fellowship is the oldest, probably, at the Institute, and one of the most successful. It would be hard to overstate the importance of the work of this fellowship, and of similar work done elsewhere, upon the quality and cost of commercial bread. The processes developed save, probably, half the yeast and half the sugar used in bread-making. One has only to compare

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the commercial bread of today with that of a few years ago to realize the enormous importance of scientific methods applied to this ancient art of the home.

The Fellowship labeled "Fiber" looks ordinary and uninteresting; but when one understands its ramifications and import, it has a different significance. One of the problems of this fellowship is the testing and development of fiber shipping containers. If one goes through a freight warehouse these days, he is struck with the lack of wooden boxes and the way in which fiber boxes and cartons have taken their place. The development of containers includes not only the study of the fiber boards, multiple and corrugated, but of the adhesive, which must be cheap and at the same time proof against storage in damp warehouses and exposure to weather.

One of the tools of this fellowship is a miniature Ferris wheel, operated by a motor and containing a series of baffles, so that a loaded container may, in a few minutes, be subjected to all the drops and bumps of a thousand, two thousand, or three thousand miles. Other tools give the actual strength of the fiber and tape employed.

The Sulphur Fellowship has a number of most interesting problems.

You will realize how enormously the production of this element was stimulated by the war, as the starting point in the manufacture of sulphuric acid, which in its turn lay at the foundation of the manufacture of explosives. Now, the war over, the companies producing sulphur in the Texas fields have an enormous excess of this element over what the markets can possibly absorb. The question is, how to use the vast sulphur deposits. Perhaps some of these present will have some ideas on the subject. A large scale use which seems possible is as a material for large acid proof containers.

Curiously enough, while the sulphur obtained from the deposits by the Frasch process is very pure (often 99.9%), the presence of a trace of oil in the sulphur makes its continued combustion in a sulphur burner difficult, because the oil forms a film which extinguishes the flame. A special burner had to be devised for the purpose.

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The Yeast Fellowship, the Flotation Fellowship, and the Coke Fellowship have problems of most far reaching character and are almost research institutes in themselves. Such fellowships are of the type called Multiple Fellowships, in which the Senior Fellow is a man of unusually high research ability, in charge of a group of investigators for the solving of a group of problems.

Fellowships like those on Synthetic Resins, Synthetic Acids, Organic Synthesis, and the Pratt Memorial Fellowship are doing work of a pure-science research character, but often on a scale of which the organic chemist rarely dreams.

The stipend carried by the fellowships at Mellon Institute is far beyond that allowed in the usual college or university. Since it is paid by manufacturers, accustomed to a business man's scale of compensation for service performed, instead of by Boards of Trustees doling out very limited funds to needy students, there is a possibility of attracting and holding men of University research character to the work of investigation. The advantage of these fellowships is further increased by the fact that by special arrangement with the donor, the Fellow may spend a limited amount of his time in graduate study or in teaching at the University of Pittsburgh. A number of Fellows have received higher degrees in this way.

The writer will close this paper with the inscription he often pondered upon during his year in Pittsburgh. It is: "This building is dedicated to the service of American Industry and to young men who destine their life work to the industries; the goal being ideal industry, which will give to all broader opportunities for purposeful lives."

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RESEARCH WORK AS A PREPARATION FOR TEACHING HIGH SCHOOL SCIENCE

FRED D. BARBER, ILLINOIS STATE NORMAL UNIVERSITY, NORMAL

On Wednesday, January 25, last, while the thermometer stood at zero, I received the following letter from the principal and teacher of physics in a high school in western Illinois.

January 24, 1922.

"Professor Barber,
Normal, Illinois.

Dear Sir:

Please be so kind as to write me which will freeze the quicker, hot or cold water. I am unable to find anything in reference to this in any of my physics textbooks. Thanking you, I am Yours truly,

.....

"P. S. The problem I have in mind is this: If a pan containing boiling water is placed in a room 10 degrees below zero, and another pan containing water at a temperature of 40 degrees Fahr. is placed in the same room at the same time, which will freeze the quicker?"

Some of us are inclined to smile at this inquiry. In reply we are perhaps inclined to suggest that authority might well be dispensed with in seeking an answer to this question, and simple observation substituted. We are even inclined to advise personal experimentation and observation to the application of abstract reasoning based upon the abstract laws and principles of physics which we all studied in our high school days. We are inclined to advise the writer of the letter to fill two similar dishes, one with boiling hot water and the other with cold water, and place these two dishes north of the school house on a cold day and observe results.

Let us not be too severe in our judgment of the attitude of this teacher. In thus seeking what he considered a reasonably authoritative statement for the solution of his problem he was undoubtedly but following the path

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along which his high school training taught him to tread. Although the Weather Bureau records will show that the entire week from January 20 to 28 showed zero weather, still it evidently never occurred to him that it was possible for him experimentally to answer his own query. His attitude of mind was not exceptionally remarkable. A fair length of life and constant observation leads me to believe that many other high school graduates are as dependent upon authority in all scientific matters as he appears to be.

Naturally, I read this letter to an advanced class in physics, and the pedagogy of physics teaching was discussed. In that class no one appeared in doubt as to whether the hot water or the cold water would freeze the sooner. One of my physics students carried the question into an advanced class in pedagogy. That class was divided in judgment as to whether the hot water or the cold water would freeze first. Not being a science class, judgments were based necessarily upon knowledge of physical laws and upon reasoning formulated upon the remembered laws and principles of physics. I was told that the discussion was animated and the conclusion was about fifty-fifty in favor of the hot and the cold water.

One member of that pedagogy class, a man of middle age, a high-school graduate and a man of many years experience as a teacher, was much interested in the question. Like the writer of the letter, he wanted a statement from some authority. He could not find it in textbooks and so he appealed to me. I questioned him as to his own conclusion. He readily gave it together with his reasons for drawing that conclusion. He said the hot water would freeze first for two reasons: First, "Physics teaches that the molecules of hot water are in rather rapid motion, while the molecules of cold water are not. Therefore, the molecules of the boiling water would come rapidly and frequently in contact with the sides of the containing vessel or to the surface. Therefore, the molecules of the hot water would lose their heat much faster than the molecules of cold water." Second, "Hot water evaporates much faster than cold water and every gram of water which evaporates carries off 536 calories of heat.

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On account of these two physical laws the hot water would cool much more rapidly than the cold water and consequently freeze sooner."

Another student went to her home near a thrifty, small city in central Illinois on Friday evening, January 27. On Saturday her father called an intelligent and experienced plumber to do some repair work on the farmhouse plumbing. The student put the question to the plumber, whether hot water or cold water exposed to zero temperature would freeze the quicker. The plumber quickly answered that the hot water would. He was certain because in his experience it was invariably the hot water pipes of the hot water heating systems which freeze and burst and not the cold water pipes of the water system. Accepting this plumber's observations as being correct, some of us may be inclined to seek knowledge relative to the location of the hot-water pipes and cold-water pipes, especially in reference to the outside walls of the house.

It is my experience that in a physics class where the practice is encouraged, hundreds of practical questions pertaining to the environment of the class and the community in which they live will be asked. Few, if any, of these questions are to be found in our ordinary textbooks or suggested in our manuals. In my judgment, in the course of the development of each unit of instruction students should be led to see and to study the relations of the principles involved as they are found in commonplace, everyday environment. From a class which has grasped this conception of the function of science study, practical questions will be forthcoming by the hundreds, and it is the most important function of the recitation or the laboratory period in a science course to answer such questions.

Illustrative of the type of questions I have in mind, permit me to state a few of them:

1. Where electric service is available, electric lighting has very generally displaced gas lighting. Generally, we also use the electric flatiron in preference to the gas or coal-heated flatiron. Why have not, likewise, electric stoves and electric heaters displaced gas stoves and coal

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furnaces and coal or oil water- and steam-heaters for house heating?

2. How can an electric company supplying current to consumers afford to maintain the pressure upon the primaries of their transformers throughout the year, day and night, when frequently, especially during the summer months, little current is consumed? This condition is true especially in villages and smaller cities.

3. Why do shunt-wound motors, running without load, or with light load, usually speed up tremenduously when large resistance is placed in series with the field coils? Why do such motors usually develop their greatest power and efficiency, when moderately loaded, when a small amount of resistance is still left in the field circuit?

4. In freezing ice cream why does the ice continue to melt even when the temperature of the contents of the freezer approaches zero Fahrenheit?

5. If an injured man is being carried up a steep hill or up a flight of stairs upon a stretcher by two other men, supposing that the center of gravity of the injured man is at the center of the stretcher, midway between the supporting hands of the bearers, is the weight of the burden equally distributed between the two carriers, one of whom is, perhaps, at an elevation of three or four feet above the other?

6. The vacuum cleaner demonstrator delights to show the hesitating purchaser that even after a rug has been thoroughly beaten on the grass or line the vacuum cleaner will still remove much dust and dirt from the rug. It is equally true that the rug receiving ordinary use and being first cleaned by a vacuum cleaner and then hung upon a line and beaten will still yield an ample amount of dust and dirt. Why is this true?

7. Frequently the unqualified statement is found in our physics textbooks that no machine can be so constructed as to yield 100% or more of efficiency when operated doing work. Is this statement true? If some employees are sent from a music store to remove a piano from the fourth story of an apartment house and they use a block and tackel to lower the piano from the fourth story window, is the statement true? Is the statement

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true when railroad men use the ordinary skids to unload a carload of barreled goods?

8. Is it true that a farmer using a very ordinary team of horses sometimes pulls a high-priced, guaranteed forty- or fifty-horsepower automobile through a bad strip of road or out of a ditch when the auto cannot make headway unaided?

A live, wide-awake high school class in physics, properly trained and actuated by a wholesome and entirely natural attitude toward their physical environment will, in the course of a year's work, ask and eagerly seek the answers to hundreds of questions similar to those mentioned. No textbook or set of textbooks can supply the answers to the legitimate questions which arise in the minds of properly trained science students.

How can a high school class in science be so trained that they naturally assume an attitude of openmindedness and inquiry concerning their environment; that they will presume that nearly every lesson will reveal the explanation of their natural surroundings? Such an attitude of mind rarely, if ever, results when the student is required to perform a hundred or so laboratory exercises as usually outlined in a manual and designed to demonstrate the laws and principles of physics. It has been my experience that but little of the apparatus usually described in our laboratory manuals or commonly found in our laboratories is patterned after or reminds the student of machines and utensils which he sees daily in use performing the necessary operations of modern life and industry. To a large extent the equipment of our laboratories is unlike the equipment of our homes and our industries. Is this necessary, to the extent that now prevails, and can we with such apparatus best teach the practical or commonly applied principles of science? If my laboratory is equipped with a Regnault's apparatus for the determination of the boiling temperature of water under pressures ranging from 2 pounds to 60 pounds, is it possible that I might substitute a common pressure cooker with a smaller range of pressure and temperature to the positive advantage of my class? Which is the more profitable experiment: To attempt to determine the calorific value

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of gas by means of an ordinary Jolly calorimeter with the usual resulting values falling far below the values required of gas companies by law, or to accept the legal calorific values and by using an ordinary gas stove determine the cost of operating that stove for one hour? Or, possibly, compare the cost and efficiency of the gas stove with an electric stove of similar size?

As I have passed through our laboratories during the past 10 or 15 years, I have been impressed with the thought that there is some tendency to substitute, to a certain extent, practical utilitarian appliances such as are seen daily in use in the ordinary walks of life for apparatus never met with outside the laboratory and used solely to illustrate or demonstrate the laws and principles of science.

I have recently been interested in looking through a new laboratory manual of physics. Of the first 25 exercises, 13 are instructions for setting up models of appliances in common use and involving physical principles. The author explains that each student is to be provided with a locker equipped with a supply of glass tubing, lamp chimneys, rubber tubing and rubber stoppers, pinchcocks, Florence flasks and such other raw materials as will enable him to construct models of useful appliances. Without counting them, I should say that about one-half of the exercises outlined are intended to be of this character. Probably the other half can safely be described as being of the old type, i. e. exercises planned to illustrate the truth of stated laws and principles and, in the main, using apparatus never used outside the laboratory.

While this laboratory manual interests me, and while I regard it as something of an innovation in laboratory practice, still I cannot approve of the method as a whole. Exercise 1 is "To construct a lift pump and explain its action". Materials required: "No. 50 Macbeth chimney; 12-oz. bottle; 12-inch, solid brass piston rod, diameter 6 mm. with cotter pins; 12-inch glass tube, outside diameter 7 mm.; No. 7 one-hole rubber stopper; No. 6 two-hole rubber stopper (one hole at the center); thin leather sheeting and tacks." Illustrations and description of the

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exercise are given. In closing, this statement is made: "The action of this pump is similar to that of the kitchen lift pump, Experiment 57. Examine the parts of this pump if the apparatus is in the laboratory." Turning to Experiment 57 we find a good, commonsense study of the "ordinary kitchen lift-pump" or rather *suction* pump. Why should any student spend time in the fitting together of glass tubing, rubber stoppers and other similar materials into a *model* of a kitchen pump when later he is asked to study the real article? Would there not be far more educational value in furnishing a group of four or five students with a real kitchen pump, a set of wrenches, and requiring them to dissect and examine the pump, sketch and describe it? In one corner of the laboratory there should be permanently mounted one such pump over a sink where its operation could be studied.

I am unable to get free from the idea that a practical course in physics for the high school should consist very largely of two parts, so far as laboratory exercises are concerned: First, we must continue to illustrate and demonstrate some of the important laws and principles of physics by means of special apparatus. Not every law or principle can be illustrated profitably, nor can all desirable quantitative relations be shown in any other way. Our laboratories must contain some equipment not found and not used in the ordinary walks of life. Second, Our laboratories should be equipped also with many of the available and commonly used pieces of machinery and utensils which involve physical laws and principles. We should banish models temporarily put together by the students and made out of glass tubing, rubber tubing, rubber stoppers, etc., playthings at best and time consumers all the while. Physics study is primarily thinking, not pottering with play stuffs.

No suggestions need be made upon the equipment of a physical laboratory to illustrate and demonstrate laws and principles or to determine such constants as should be determined. This custom is established. I think it is desirable to suggest that a laboratory should be equipped with many practical, rather small but life-sized, portable,

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and where possible, dissectable commercial appliances commonly used in the life of every community. What are a few of these commercial appliances? Cistern pumps, coal stoves, gas stoves, electric stoves, meters of every kind (gas, water and electric), water and electric motors, gasoline, gas and hot-air motors, pressure cookers, heat regulators, electrical transformers, rectifiers for changing ordinary 110 volt A. C. to low voltage D. C., ice and mechanical refrigerators, cameras, telescopes, opera glasses, transformers and X-ray outfits, some musical instruments, blood-pressure apparatus and such other appliances as involve physical principles and are suitable and available. The list should include eventually practically every appliance which is not too large or costly which is found in the community.

If some of our laboratory periods are to be spent in experimentally answering practical questions which arise in the class recitation and not to be found in text or manual, how much will our ordinary laboratory methods be modified? Suppose that the following question has been raised in the class during the discussion of why electricity has not so completely displaced gas in cooking and heating as it has in lighting: What is the relative cost and time required to raise a quart of water from tap temperature to the boiling point, first, by using a gas stove or hotplate and, second, by using an electric stove or hotplate? It is then the teacher's duty to plan an exercise which will answer the question. In my judgment it is neither feasible nor desirable that high school students make such investigations individually. Class or group work is entirely sufficient. This does not mean that the teacher should give this rather lengthy exercise as a clear-cut demonstration while the class looks on. If the group consists of no more than 10 to 15 students the teacher can stand aside and assign the duty of making the proper connections to certain students. Other students may be assigned the task of inspecting those connections. Still other students may later be assigned the duty of reading the meters and taking the temperature and time.

To conduct such a group experiment, perfect order and careful attention must be required of every student.

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Frequent questioning should be the rule. Each piece of data must be clearly announced, or better still, recorded upon the blackboard. Each student should be held strictly for the proper recording of data as the experiment proceeds, and likewise for adequate sketches of apparatus and all connections. Such an exercise is justified only upon the ground that thinking and thoroughly understanding every detail of the exercise is an imperative requirement. I doubt if it is nearly so difficult to secure such results when conducting a group exercise as it is when overseeing 10 to 20 students at individual experiments.

Now as to the subject of this paper: Research Work as a Preparation for Teaching Science. If, as this paper assumes, about one-half, or thereabouts, of the laboratory exercises are based upon the study of situations arising out of the questions proposed by the class and not to be found, asked or answered in the text or manual, then the burden of determining just how those investigations are to be made falls upon the instructor. If such investigations are attempted, the instructor must plan many exercises. In my opinion the fitting of the laboratory work, as far as possible, into the environment of the class, making the laboratory investigations reveal the facts about the physical world about us, is a sure way of securing true values, lasting interest, and vital coöperation on the part of the students.

The science teacher who has received considerable training in research work is, in my judgment, much better fitted to conduct experimentation, suggested by class questions or class discussion, than is the teacher who has received no training in research work. Reliable judgment as to the soundness and reliability of methods to be used is a necessity. The teacher must also be prepared to defend the conclusions reached. Teachers of science who have been dependent, all their lives, largely upon the authority of the textbook for conclusions and upon the laboratory manual for the methods of experimentation are not well prepared to have the class ask questions not discussed in either text or manual. Such science teach-

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ers will continue doubtless to adhere strictly to the recitation of the laws and principles from the text and to the performing of only those exercises which are outlined in the manual.

Is it not possible that the writer of the letter quoted at the beginning of this paper lacked the self-confidence and initiative needed to stimulate him to investigate the matter as to whether hot water or cold water freezes first because his training has never included any work in research? This paper is no appeal for the injection of ordinary university research work into the high school curriculum. It merely makes the suggestion that if the spirit of the research worker and his attitude toward unsolved problems were frequently and skillfully injected into high school science classes and always applied toward clearing up situations found in the student's environment or in the community, there would be less stereotyped, uninteresting and unprofitable science teaching.

Is this picture of fitting at least a part of science study in the high school onto the environment of the students farfetched and visionary? Is there a science teacher in this audience who has not felt an immediately stimulating interest arise in the class when some student springs a vital question which relates the general topic under discussion to a concrete situation in which they are all concerned? Recently I had such an experience. We had studied the short-distance and the long-distance telegraph systems. One young man, without any suggestion on my part, went to a Western Union station and asked questions. When he reported to the class that the operator told him that the Western Union Telegraph Company had discarded the local circuit from many small stations on their lines and were largely using "main line" sounders, except at central stations, the interest of the class was much aroused. When the initiative for study comes largely from the science class itself, then we shall have more productive and more educative science teaching.

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CONTENT OF THE HIGH SCHOOL COURSE IN CHEMISTRY

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It is barely a matter of two decades ago since chemistry began to be transferred from the college to the high school as a well established course of study. It is perhaps for this reason that high school chemistry has persistently clung to its inherited character of a college subject pared down, made easy, and sugar coated with "practical applications" to make it more palatable to the recalcitrant young minds.

It is the purpose of this paper to offer a suggestion by which the high school and college freshman chemistry courses may be sharply differentiated so as to make the one a real foundation course and the other a distinct advance in the learners progress. The constant overlapping of these two courses, with the consequent loss of motion and hence interest in the subject, is familiar to all teachers of chemistry. In the average high school text there are the usual chapters on fundamental laws and principles, hydrogen, oxygen, water, hydrochloric acid, the halogens, salts, acids, bases, solutions, ionic theory, the metals, the periodic law, and so on to a grand finale on the wonders of radium or a mighty explosion in the Panama Canal. Then, to those whose enthusiasm has been sufficiently aroused to carry them into the freshman class, comes a dreary rehash of the whole program, the only practical difference being that the young freshman has to pay more for his text book.

In order to arrive at some conclusion as to the nature of the present day high school course in chemistry, six of the most widely used chemistry texts in Illinois high schools were analyzed by paragraph count, classing the paragraphs under the following three heads:

1. Fundamental Principles.
2. Descriptive Matter.
3. Practical Applications.

Under the first head were included paragraphs dealing with fundamental principals and laws, such as the weight

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laws, gas laws, definitions, theories, formula making, equation writing, etc. Under the second head were included paragraphs of a purely descriptive nature, dealing with such matters as occurrence, preparation, properties and uses of the elements and of their compounds. Under the third head were included paragraphs of a purely practical nature, such as water purification, glass blowing, acetylene welding, air purification, and the like. The following table exhibits the "chemical composition" of the books examined:

COMPARISON OF TEXTS, ELEMENTARY CHEMISTRY.

Text	Fundamental Principles	Descriptive	Practical Applications
Brownlee and Others (1921)..	27.0%	63.3%	9.7%
McPherson and Henderson (1905-1907)	24.1	64.6	11.1
Newell (1914).....	18.1	75.8	6.1
Hessler and Smith (1912-1921)	31.6	65.9	2.5
Dull (1918-1921).....	27.8	56.5	15.9
Black and Connant (1921)....	28.2	63.5	8.2
Averages	26.1	64.9	8.9

From the above tables we see that in spite of the authors' prefatory promises as to uniqueness, the texts examined run very true to type. About one-fourth to one-third of the space is allotted to basic principles, while the rest is given over to the usual descriptive matter with here and there a sprinkling of practical applications amounting to an average of less than ten percent of the whole.

For some years past the writer has been associated with work in high school chemistry in an advisory capacity, at the same time conducting a first course in college. This has offered an opportunity for developing two distinct and complementary courses, each course distinct as to content and the one preparing for the other.

The beginning course is a course in fundamental and general principles only. The divisions are sections, each section dealing with one law or general principle. The principle is first stated and then followed by any necessary explanatory sentences. Then follows a series of experiments illustrating the principle or law in question, each experiment containing a general statement of meth-

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od, detailed experimental directions, and questions intended to show how the results of the experiment illustrate the law. The emphasis is on fundamental principles rather than on processes. To illustrate: This course does not contain an experiment the "object" of which is "to make hydrogen", but under the section dealing with the action of acids on metals there is a statement of this principle: Active metals displace hydrogen from acids. Under this principle there are experiments showing the action of various acids on various metals. Thus the principle involved in these experiments is kept to the fore, and the learner comes through with this in mind rather than with the idea that he has learned how to make hydrogen. The relative value of these two ideas as a net "result" of the experiment is easy to see. Fundamental and general principles are the a-b-c's of any science. The learner makes no real progress until they begin to take shape in his mind, and the proper place for this process to start is at the beginning. Subsequent courses will then serve to broaden and deepen these concepts and he will then gain the correct scientific viewpoint, i. e. he will learn to view the varied and complex phenomena of the world around him in the light of fundamental laws and general principles.

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MELTING POINT, LATENT HEAT OF FUSION AND SOLUBILITY OF ORGANIC COMPOUNDS

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Introduction

Commercial laboratories as well as educational laboratories which are working with organic compounds are constantly confronted with questions having to do with solubility and choice of solvent for use in purifications. In the great majority of cases the desired information is not available from the published data. In such cases it is necessary either to determine the solubility experimentally or to resort to some method of calculation. The more successful of the various methods used for calculating solubility generally employ an equation involving Raoult's freezing point law together with the second law of thermodynamics. Perhaps the simplest and most useful of these expressions is,—

$$\log N = \frac{-L}{4.58T} + I \qquad (1)$$

In this expression N represents the mole fraction of the solute. (By solute is meant, that component which first crystallizes out in the pure state upon cooling the system). L is the molecular latent heat of fusion, T is the absolute temperature of the melting point of the system and I is an integration constant.

In general it may be said that these equations have been successful only for the so called "ideal" mixtures. By ideal mixture is meant those binary systems, the components of which may be considered to have the same thermodynamic environment when both are in the liquid state and both are at the same temperature. Two of the criteria for such a system are that there shall be neither any heat effect nor any volume change when the two liquid components are mixed. The complete absence of any secondary molecular effects, such as association and compound formation, is implied in the definition. Therefore, if in any case the heat effect for the solution process of dissolving a solid in a liquid differs from the latent heat of fusion of the solute at the temperature

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in question, then this simple form of the solubility law does not express the true solubility.

Hildebrand,[1] in a series of very able papers, has shown that the degree to which a given binary mixture of non-polar substances departs from the formula for ideal mixtures is closely related to the magnitude of the differences in internal pressures of the components. In the fourth paper of the series, he has described a method for evaluating solubility data, and has indicated how the solubility of many substances may be approximately calculated providing the solubility of the given substance has been determined in solvents having a similar internal pressure to that of the solvent in question.

In evaluating solubility data Hildebrand plots the common logarithm of the mole fraction of solute against the reciprocal of the absolute temperature of the melting point of the system. The experimental solubility points when plotted in this manner should, if there are no secondary molecular effects, lie on a straight or only slightly curved line over fairly wide ranges of temperature. When the solubility curves of a given solute in a variety of solvents are plotted in this way, there is obtained a series of lines, which converge to a point at the melting temperature of the solute where $N = 1.0 (\text{Log } N = 0.0)$

According to the hypothesis put forward by Hildebrand, the nearer the internal pressures of the liquified solute is to that of the solvent in question, the nearer will the experimental curve approach to the ideal solubility curve calculated from the latent heat of fusion of the solute. Therefore, if two solvents should be found to have exactly the same internal pressures, then the molecular solubility of each solute should be the same for the two solvents. Hildebrand[2] has prepared a table of relative internal pressures from which, having a series of solubility curves for each solute, the solubility curve of any such solute may be located approximately for any other solvent, the position of which, in the table of relative internal pressures, is known.

The obvious disadvantages of this method of calculating solubilities are: first, the internal pressures are known for only a relatively small number of substances.

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Second, the method has not been applied to polar solvents. Third, in any case, the solubility must have been determined in a series of selected solvents before the solubility in other solvents may be calculated.

In the pages which follow we have described a method of calculating solubilities which requires but a minimum of physical measurements and which will apply to polar as well as to non-polar solvents providing there are no molecular compounds or solid solutions produced. It should be possible also to tell which systems will give partially miscible and which immiscible liquid systems.

DEVELOPMENT OF METHOD

From equation (1) it is evident that the slope of the log N vs. 1/T curves is related to the latent heat of fusion of the solute in the following manner,

$$\text{Slope} = S = \frac{\Delta \log N}{\Delta (1/T)} = \frac{-L}{4.58} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation (2) applies only to those binary mixtures in which the heat effect of the solution process is equal to the latent heat of fusion of the solute. Now it is a general rule, providing no secondary molecular effects are produced, that the negative heat effect accompanying the solution process is greater than the latent heat of fusion. In all such cases the slope of the logarithmic curves must be greater than that of the ideal slope. This is well shown in Table 1.

The ideal slope for any solute is that slope which would be obtained with a solvent which gives a thermodynamically ideal mixture. It is evident from Equation (2) that the value of the ideal slope may be calculated by dividing the latent heat of fusion of the solute (in small calories per mole) by the constant 4.58.

If now the experimental values of the slopes of the log N vs 1/T curves for a given solute in a variety of solvents be divided by the value of the ideal slope for that solute, there is obtained a series of factors the magnitude of which is a measure of the non-ideality of the mixture.

In Table 1 are given values of the slopes and of the factors which have been calculated for the four solutes,

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Naphthalene, Fluorene, Benzoic Acid and Urethane. A glance at the solubility relations of these four substances shows that the solvents which come the most nearly to forming ideal solutions are the aromatic hydrocarbons with their halogen and nitro derivities. These are followed by the substances having lower internal pressures such as ether, carbon tetrachloride, the esters and acid anhydrides and also by the substances having higher internal pressures, the amines, acids, alcohols and water.

Comparing the solubility relations of naphthalene and fluorene, it is found that the relative positions of the log N vs. 1/T curves are the same for both substances. Hence it may be concluded that the internal pressures of these two solutes are nearly the same.

When we come to consider the solubility relations of benzoic acid, it must be remembered that this substance is moderately polar; hence the moderately polar solvents, or those having moderately high internal pressures, come the most nearly to giving ideal mixtures. Finally, it is evident from Table 1 that urethane has an internal pressure corresponding to that of the lower alcohols. The very high slope obtained for this substance in toluene should be noted. It will be observed that the highly polar substance, water, is a better solvent than is toluene.

In order to coordinate these solubility relations and many others which have been studied we have made use of the chart shown in Fig. 1. It will be observed that the

TABLE 1.

Slopes of the log N vs. 1/T curves for the solutes Naphthalene, Fluorene, Benzoic Acid, and Urethane and the values of the factors obtained by dividing the experimental slope by the ideal slope.

SOLUTE—NAPHTHALENE.

Solvent	Slope of the log N vs. 1/T curves	Experimental slope / Ideal slope	Factor taken from Fig. 1
Ideal solvent	970	1	1
Diphenylamine	960	1–	1–
Fluorene	970	1	1
Phenanthrene	970	1	1
Chlorbenzene	970	1	1
Ethylene dichloride	980	1.01	1.01
Ethylene dibromide	990	1.02	1.02
Nitro benzene	1010	1.04	1.05

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SOLUTE—NAPHTHALENE—Concluded.

Solvent	Slope of the log N vs. 1/T curves	Experimental slope / Ideal slope	Factor taken from Fig. 1
Benzene	1020	1.05	1.06
Toluene	1030	1.06	1.07
Phthalic anhydride	1040	1.07	1.09
Carbon disulfide	1050	1.08	1.11
Pyridine	1060	1.08	1.10
Ethyl acetate	1160	1.20	1.19
Ether	1180	1.22	1.22
Thymol	1200	1.24	1.30
Acetone	1260	1.30	1.33
Para toluidine	1270	1.31	1.35
Alpha naphthylamine	1270	1.31	1.32
Alpha naphthol	1310	1.35	1.40
Aniline	1430	1.47	1.45
Phenol	1700	1.75	1.75
Hexane	1740	1.80	1.80
SOLUTE—FLUORENE.			
Ideal solvent	1050	1	1
Chlorbenzene	1060	1.01	1.01
Nitro benzene	1090	1.04	1.04
Benzene	1180	1.12	1.10
Pyridine	1200	1.14	1.10
Carbon disulfide	1210	1.15	1.12
Carbon tetrachloride	1320	1.25	1.22
Aniline	1510	1.44	1.35
Acetone	1580	1.50	1.37
SOLUTE—BENZOIC ACID.			
Ideal solvent	900	1	1
Acetone	940	1.04	1.04
Benzil	940	1.04	1.04
Acetophenone	940	1.04	1.04
Phenol	1190	1.32	1.35
Nitro benzene	1200	1.33	1.34
Toluene	1370	1.52	1.47
Benzene	1380	1.53	1.45
Acetic acid	1460	1.62	1.58
Carbon tetrachloride	1530	1.70	1.67
SOLUTE—URETHANE.			
Ideal solvent	795	1	1
Methyl alcohol	925	1.17	1.22
Acetamid	950	1.19	1.22
Acetanilid	950	1.19	1.22
Ethyl alcohol	1060	1.33	1.43
Probyl alcohol	1200?	1.50–1.75	1.62
Amyl alcohol	1500?	1.75–2.00	1.90
Water	2000?	2.25–	2.35?
Toluene	2600?	3.00–	3.65?

right and left sides of this chart are the same, except that one side is the inverse of the other. On the left side of the chart the internal pressures increase downward while on the right side they necessarily increase upward. The figures in the middle of the chart, increasing both upward and downward from unity, are the factors ob-

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FIG. 1.

CHART OF RELATIVE INTERNAL PRESSURES

	5	resoroin
hexane	4	acetamid urethane
paraldehyde ether ethyl acetate, acetic anhydride carbon tetrachloride phthalic anhydride toluoie benzole, dihalides, bromo derivitives acenaphthene naphthalene, phenanthrene, diphenylamine	3	hydrochinone methyl alcohol ethyl alcohol
fluorene anthracene, nitro derivitives di and tri phenylmethanes nitro halides, pyridine, pyrrol carbazole, carbon disulphide nitro phenols benzanthrone anthraquinone benzophenone acetophenone, benzil, thynol acetone, alpha and beta naphthylamine o— m— p— toluidines benzoic acid alpha and beta naphthol, trichloracetic acid cresols, aniline	2	propyl alcohol butyl alcohol
phenol acetic acid	1	

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	2	acetic acid phenol
butyl alcohol propyl alcohol	3	aniline etc A— and B— naphthol benzoic acid o— m— p— toluidines acetone etc. acetophenone etc. benzophenone anthracuinone benzonthrone nitro phenols carbon disulph. nitro halides triphenly nethane nitro derivitives fluorene
ethyl alcohol methyl alcohol hydrochinone	4	naphthalene etc. acenaphthene benzole etc. toluole phthalic anhydride carbon tetrachloride ethyl acetate etc. ether paraldehyde
urethane acetanid	5	hexane
resoroin		

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tained by dividing the experimental slopes of the log N vs. 1/T curves by the ideal slope calculated from the latent heat of fusion.

In this chart naphthalene has been taken as the starting point. The value of the ideal slope is taken to be 970. This corresponds to a latent heat of fusion of 4,450 calories per mole, a value which is somewhat less than

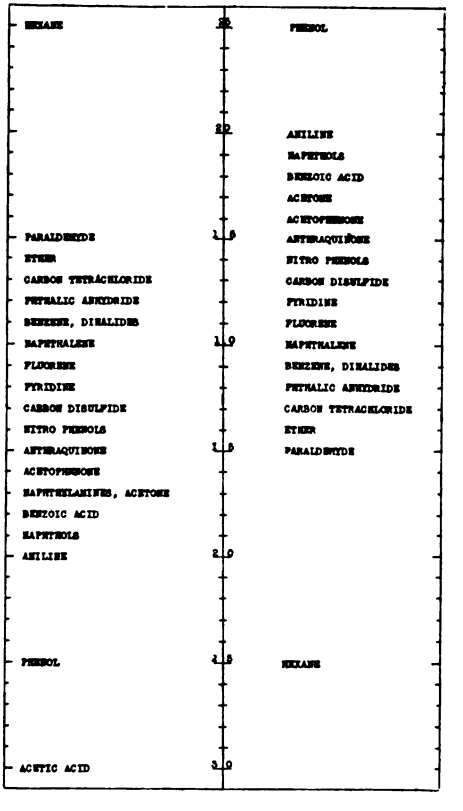

Fig. 1.
Chart of Relative Internal Pressures.

that commonly accepted for naphthalene, viz., 4,550 calories. In order to fix the positions of the other substances relative to naphthalene, it was found convenient to locate first those substances which had been used as solvents for naphthalene. Now a large number of freezing point and solubility curves of binary systems involving naphthalene as solute are given in the literature.

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Of this number about twenty appear to have been determined with the required degree of accuracy. The experimental slopes of each of these curves are given in Table 1, together with the value of the factors obtained by dividing the experimental slope by the ideal slope, 970. Each factor was then located on the middle line, and a straight edge was so placed across the chart that it passed through this factor and the point chosen for naphthalene. The point at which this line cuts the opposite side of the chart is the location of the substance in question. Having located these substances they were then used in finding the location of other substances, the binary systems with naphthalene of which had not been determined.

In making the calculations involved in finding the location of these other substances in the chart it was often found that the positions of the substances already fixed in the table could be checked repeatedly. In all cases shown the positions finally adopted are the mean values of several closely agreeing experiments using different solutes or solvents.

It will be observed that there may be some question, especially where the factor has a value near to unity, as to whether the factor should be slightly above or slightly below the ideal position. In deciding this question one may be guided somewhat by Hildebrand's table of relative internal pressures and also by the solubility relations in other systems.

In making the complete table we have calculated to mole fractions the solubility and freezing point measurements of over 400 binary mixtures. Not all of the substances studied appear in the chart. There have been a large number of isolated systems investigated which need only a few measurements in order to coordinate the complete solubility relations of these substances. We hope soon to make these measurements and to publish the results in a later communication.

USES AND LIMITATIONS OF THE CHART

The uses of this chart are quite evident from the foregoing discussion. In the first place it may be used to

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calculate the freezing point curve or the solubility of any substance in the table with any other substance in the table providing the latent heat of fusion (ideal slope of the log N vs. 1/T curves) is known and the assumption is warranted that there are no complicating molecular effects. In making the calculation all that is necessary is to find the factor by which the ideal slope must be increased in order to make it equal to the slope which would be determined experimentally. This factor is found by placing a straight edge across the chart in such a position that it joins the components of the desired system. The point at which this cuts the line of factors will then be the ratio sought. Evidently, the nearer two substances are to one another in the table, the more nearly will their reciprocal solution approach to that of the ideal mixture. A comparison of columns 4 and 5, Table 1, will indicate the degree of precision to be expected.

In determining molecular weights by the melting point or boiling point methods, one should choose a solvent which has approximately the same position in the chart as the solute to be used. If this rule is not followed it will be observed that the "molecular association" of the solute will appear to increase in direct proportion to the magnitude of the factor relating the solute and solvent in the above chart.

In this connection, it is commonly assumed that acetic acid in benzene solution (benzene = solute) is associated into double molecules as determined from the Van't Hoff freezing point laws. In making that assumption, the further assumption has been made that the heat of the solution process is equal to the latent heat of fusion. In many ways it is more tenable to assume that in those systems which give fairly straight logarithmic solubility curves, at least, the variation from the normal is in the heat effect rather than in the molecular weight of the dissolved substance. This view is further supported by the fact that when molecular complexes are formed very highly curved solubility curves are obtained.

This chart should also aid in the choice of solvent to be used in recrystallization and in the choice of extract-

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ing solvents. In this connection the question may be asked, What mixtures of substances will form immiscible liquids? It has been observed that when the difference in internal pressures of the substances is so great that the factor connecting them in the above chart has a greater value than about 4.0—4.5 partially miscible liquids may be expected to occur. In general the higher the melting point of the components the greater must be the difference in internal pressure to cause a separation into two liquid phases. When the factor between two components is greater than 5.0—5.5 the substances may be considered as practically immiscible. Mixtures of two compounds containing enolic or ketonic oxygen may not follow this rule due to the formation of oxonium compounds.

In making the calculations involved in constructing this table some generalizations have been observed which, although probably well known, will be valuable in placing other substances in the table and also in showing the uses and limitations of this method of calculating solubility.

It has been found that structural isomers very seldom form mixed crystals or chemical compounds; phenanthrene and anthrecene, however, do form an unbroken series of mixed crystals.

Structural isomers generally have very nearly the same internal pressures; hence the freezing point curves between isomers are useful in determining the "ideal slope". Resorcin and hydrochinone are apparently exceptions to this rule.

It has been observed that when substances containing hydroxyl groups enter into systems containing enolic or ketonic oxygen, positive deviations from Raoult's law may be expected to occur, i. e., the solubility will be greater than that calculated from the principles outlined above.

A typical exception to this rule is found in the system Resorcin-Water, the log N vs. 1/T curve for which is almost a straight line.

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Binary systems of similarly constituted molecules may be expected to form mixed crystals. Examples are:

para chlor nitro benzol—para brom nitro benzol.
para brom toluene—para iodo toluene.

It is interesting to note that substances having simliar structures occupy approximately the same place in the table, thus:—

Acetone, benzophenone, acetophenone, benzil.
Pyridin, pyrrol, carbazol.
Ethers anhydrides, esters.
Simple amines.
Simple nitro derivitives.
Simple halogen derivitives.

In describing the above method of calculating solubility we have made the assumption that the log N vs. 1/T curves having the ideal slope is known or may be determined. We shall now consider some of the methods of obtaining this ideal slope in cases where it is not known.

METHODS OF FINDING LATENT HEAT OF FUSION AND IDEAL SLOPE

The method which has been found to give the most consistent results is the following. There is first obtained a complete freezing point curve of the substance in question, for convenience called A, with some other substance, B, the ideal slope for which is known and the position of which in the chart of relative internal pressures has been determined. In choosing the exact binary system to be used it is necessary that there shall be no molecular complexes formed in the solution, and it is convenient to choose as the second component a substance having about the same melting point as that of the substance to be investigated. The factor to be used between solute B and solvent A is first determined by dividing the value of the ideal slope for B into the value experimentally obtained when the substance A, of unknown internal pressure, is used as solvent for B. Having determined this factor, the position of the substance A in the chart may be found. If now the substance A be used as solute B, or any other substance whose position in the chart is known, be used

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as solvent and the slope of the log N vs. 1/T curve of the system is determined, then the ideal slope for A is obtained by dividing this experimental slope by the appropriate factor obtained from the chart, Fig. 1.

From the ideal slope so obtained the latent heat of fusion of the solute may be calculated. This is done by multiplying this ideal slope by the constant 4.58 which gives the latent heat in calories per gram mole. In Table 2 are given some values of latent heats calculated in this way. It will be observed that these values compare favorably with those determined calorimetrically.

A second method for determining the ideal slope and the position in the table may be called the "cut and try" method. This method may be used in those cases in which the solubility of a solute has been determined in a series of solvents whose positions in the chart have been determined. It is evident that there is only one position in the chart which will satisfy the demands of the factors of more than one solvent when the solute has been given any value for the ideal slope. The object is to find that set of values for the ideal slope and for the position in the chart which comes the most nearly to fitting all of the solvents involved. Evidently only two such solvents are needed, but if more have been investigated greater confidence may be placed in the results obtained.

A third method for determining the ideal slope of the log N vs. 1/T curves may be used in those cases in which L, the latent heat of fusion, is accurately known. This is seldom the case, however. It is regretable that such an important physical property has been so long neglected. In cases where it has been determined the results are often so discordant that doubt is thrown upon much of the published data. This variation is due, partially at least, to the fact that many of the values have been calculated from Van't Hoff's equation and hence the values obtained will depend upon the nature of the solvent used.

In table 2, column 5, have been tabulated the latent heats of fusion of a representative number of organic compounds. These values have been taken largely from Landolt and Boernstein, Tabellen, and only those results which have been calorimetrically determined are includ-

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ed. In the 4th column of this table are given the latent heats of fusion as calculated from the ideal slopes of the log N vs. 1/T curves. Finally, in column 6 are given the quotients obtained by dividing the calculated molecular latent heat of fusion expressed in small calories by the absolute melting point of the substance. This, according to Walden,[3] should equal about 13.5. It will be observed from table 2 that the constant, 13.5, applies very well to most halides and nitro compounds and to many other isolated compounds, especially to those substances which have relative high molecular weights and moderately high melting points. In general, it may be said that the Walden constant for the more highly polar substances such as the hydroxide, ketones, amines, etc., has a value somewhat smaller than the normal. In any case, it should be possible, by reference to table 2, to calculate an approximate latent heat of fusion and hence the ideal slope for any substance whose structure and melting point are known. Presuming the structure to be known, it is then possible to locate approximately the position of the substance in the chart, Fig. 1. With this information it is then possible to calculate the solubility of the substance in question in all of the substances shown in the table which do not form molecular complexes or solid solutions. Thus it is seen that a fair idea may be had of the solubility relations of any given substance from only the melting point and structure of the solute.

The application of the principles outlined above should aid materially in the choice of solvent for crystallizations and also in the choice of solvent for use in molecular weight determinations.

TABLE 2.

The Latent Heat of Fusion of Organic Compounds.

HYDROCARBONS.

Substance	M. Pt. Abs. (Tm)	Ideal Slope (Si)	S_i 4.58 (L calc.)	Lobs.	L calc. / Tm
Benzole	278.5	510	2330	2350	8.36
Para xylole	287.4	840	3840	4170	13.4
Diphenyl methane	299.3	810	3700	....	12.4
Diphenyl	343.2	960	4390	4390	12.8
Naphthalene	353.1	970	4440	4550	12.6
Triphenyl methane	366.0	970	4440	....	12.6

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HYDROCARBONS—Concluded.

Substance	M. Pt. Abs. (Tm)	Ideal Slope (Si)	Si. 4.58 (Lcalc.)	Lobs.	Lcalc. Tm
Acenaphthene	366.5	1090	5000	....	13.6
Phenanthrene	371.0	980	4470	....	12.1
Fluorene	386.5	1050	4800	....	12.4
Pyrene	421.0	1150	5260	....	12.5
Anthracene	489.6	1500	6870	6890	14.0
HALIDES.					
Ethylene dibromide	282.8	550	2540	2540	9.0
P-brom toluole	299.8	800	3680	3650	12.2
P-dichlor benzole	325.5	960	4400	4390	13.5
P-dibrom benzole	360.0	1060	4850	4860	13.5
P-diiodo benzole	401.0	1200	5500	....	13.7
NITRO COMPOUNDS.					
P-nitro toluole	324.3	800	3660	....	11.3
Alpha nitronaphthalene	328.0	950	4340	4380	13.2
1-3-4-dinitro toluole	332.0	990	4520	....	13.6
1-2-6-dinitro toluole	338.0	1000	4570	....	13.5
1-2-4-dinitro toluole	344.0	1020	4650	....	13.5
M-dinitro benzole	363.0	1070	4900	4870	13.5
O-dinitro benzole	389.5	1160	5300	....	13.6
NITRO HALIDES.					
P-fluor nitrobenzole	299.5	710	3240	....	10.7
O-chlor nitrobenzole	305.3	850	3900	....	12.8
O-brom nitrobenzole	311.2	900	4110	....	13.2
M-chlor nitrobenzole	315.8	930	4250	4630	13.5
P-chlor nitrobenzole	357.0	1060	4850	....	13.6
P-brom nitrobenzole	396.5	1200	5490	....	13.8
P-iodo nitrobenzole	446.0	1500	6850	....	15.3
1-2-4-dichlor nitrobenzole	313.6	810	3700	....	11.8
AMINO COMPOUNDS.					
Aniline	267.5	425	1940	1940	7.26
P-toluidine	316.5	870	3980	....	12.6
Alpha naphthylamine	317.7	680	3110	....	9.8
Diphenyl amine	325.7	880	4020	4050	12.3
O-nitraniline	343.0	840	3840	....	11.2
M-nitraniline	387.0	1000	4570	....	11.8
P-nitraniline	421.0	1100	5030	....	11.9
OXYGEN CONTAINING SUBSTANCES.					
Meta cresol	277.3	380	1740	....	6.3
Ortho cresol	303.7	475	2170	....	7.15
Phenol	313.6	495	2260	2340	7.2
Alpha naphthol	367.5	1120	5120	....	13.9
Beta naphthol	395.0	1150	5250	....	13.3
Resorcinol	383.4	565	2580	....	6.73
Hydrochinone	443.0	705	3220	....	7.3
Thymol	322.2	650	2970	2980	9.2
Menthol	315.0	650	2970	2950	9.4
Paraldehyde	285.0	615	2820	....	9.9
Phthalic anhydride	403.8	1070	4900	....	12.1
Acetophenone	293.5	....	....	3980	....

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OXYGEN CONTAINING SUBSTANCES—Concluded.

Substance	M. Pt. Abs. (Tm)	Ideal Slope (Si)	Si. 4.58 (Lcalc.)	Lobs.	Lcalc. Tm
Benzophenone	322.0	830	3800	4310	11.8
Benzil	388.0	1020	4650	4650	12.0
Anthraquinone	558.0	3560	7780	7780	13.9
Acetic acid	289.4	320	1460	2630	5.05
Trichloracetic acid	330.0	775	3540	....	10.7
Beta oxynaphthoic acid	489.0	1440	6580	....	13.5

MISCELLANEOUS SUBSTANCES.

Urethane	318.2	795	3630	3630	8.03
Carbazole	518.0	1400	6400	7050	12.3
Acetamid	350.0	480	2200	....	6.3
Ortho nitrophenol	319.0	810	3700	3720	11.6
Meta nitrophenol	367.5	1080	4950	....	13.5
Para nitrophenol	386.0	1150	5260	....	13.6
1-2-4-dinitrophenol	384.0	1140	5210	....	13.6
Picric acid	395.5	910	4160	....	10.5

SUMMARY

There has been developed a method for calculating solubility based upon Raoult's ideal freezing point law and employing an empirical method for determining the actual deviation from the ideal.

A method for calculating the latent heat of fusion from solubility data has been described.

Some generalizations regarding the results to be expected with various types of binary systems are discussed.

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THE EFFECT OF ALKALI VAPORS AND OTHER GASES AT VARIOUS PRESSURES IN THERMIONIC DETECTORS

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INTRODUCTION

In recent years there has been put on the market, and used extensively, a class of vacuum tubes known as "gas content detector tubes". The advantage of using this type of tube as a detector lies in the fact that it does not require a high plate voltage for its operation; in fact, the plate voltage is often as low as 18 volts, but must be adjusted carefully to the best value for loudest signal response. For such tubes the adjustment of filament current is also critical, and these two characteristics constitute a serious disadvantage. In the case of higher vacuum tubes used as detectors adjustments are not so critical, which of course is a distinct advantage, the only disadvantage being that higher plate voltages are necessary for good audibility of signal response. During the past year, and recently, considerable work was done by the authors of this paper on the effect of variation of pressure and nature of gas content upon the efficiency, constants, and characteristics of detector tubes. It is not within the scope of this paper to describe the work in detail, but the results and conclusions will be reviewed, together with some of the more important curves.

Several tubes were connected to a condensation pump and vacuum gauge, see diagram A, and for various pressures readings were taken of plate voltage for loudest signal reesponse, called the "operating voltage". Readings were also taken of percent signal intensity when the tube was operating as a detector of undamped waves. Typical results are shown in Fig. 1. It will be noticed that the operating voltage decreases very rapidly with a slight increase of pressure above the high vacuum stage, and that the maximum audibility occurs at rather good vacua, .002 to .004 mm. of mercury, and for operating voltages of from 40 to 50 volts. The percent signal in-

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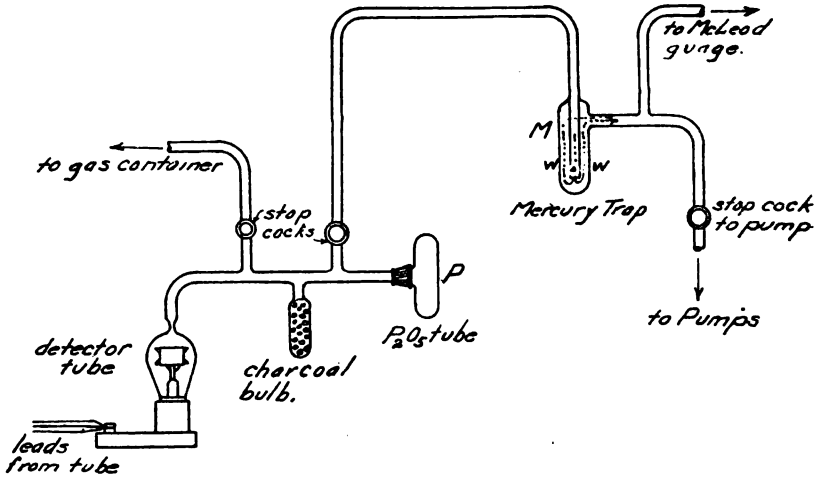
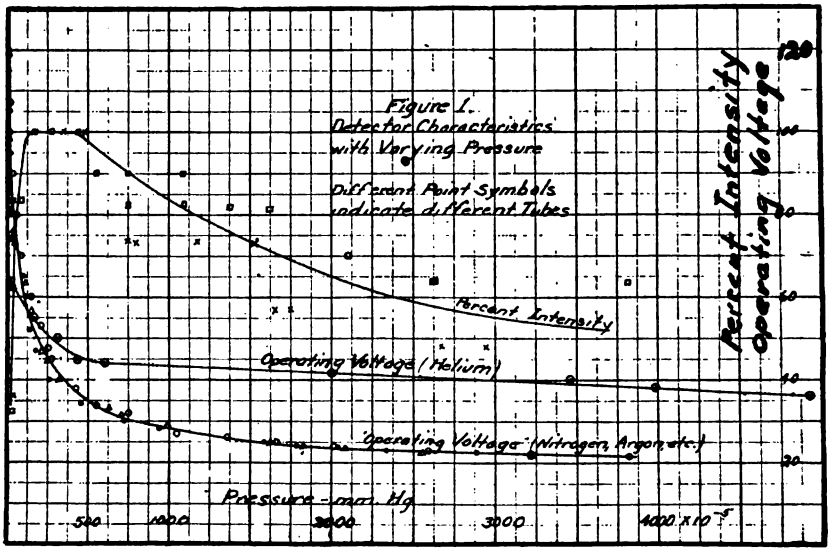


Diagram A
Vacuum Connections.



tensity was determined by the method of comparisons with a variable standard, recommended by Van der Bijl on page 337 of his book, "The Thermionic Tube". The circuit and equipment actually used is shown in Diagram B. D is the tube under test, Ds is the standard tube with which the signal strength from oscillator is ad-

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justed to a certain value. The variable signal standard for comparisons is furnished by means of tube S. T., audibility meter N being used to attenuate this signal in a given ratio to match that from D. Choke coils A and A[1] are used to maintain constant potential between plate and filament when the audibility meters are changed. Space cannot be given to a complete discussion of this apparatus. It should be mentioned here that in all signal intensity measurements, a weak signal, having a directly measured audibility of 5.5 times on a standard tube, was furnished to the receiving circuit connected to the tube under test. The curves of Fig. 1 are typical for several tubes tested, the gas content being air or nitrogen or neon, etc. The figure also shows the operating voltage curve for a tube with different gases which were introduced successively. In order to determine the effect of various kinds of gases upon the sensitiveness of a detector tube, different gases were introduced successively into the same tube and signal intensity comparisons measured for each gas. The tests were repeated several times for the same tube, and for different tubes, so that the results were conclusive. Hydrogen, nitrogen,

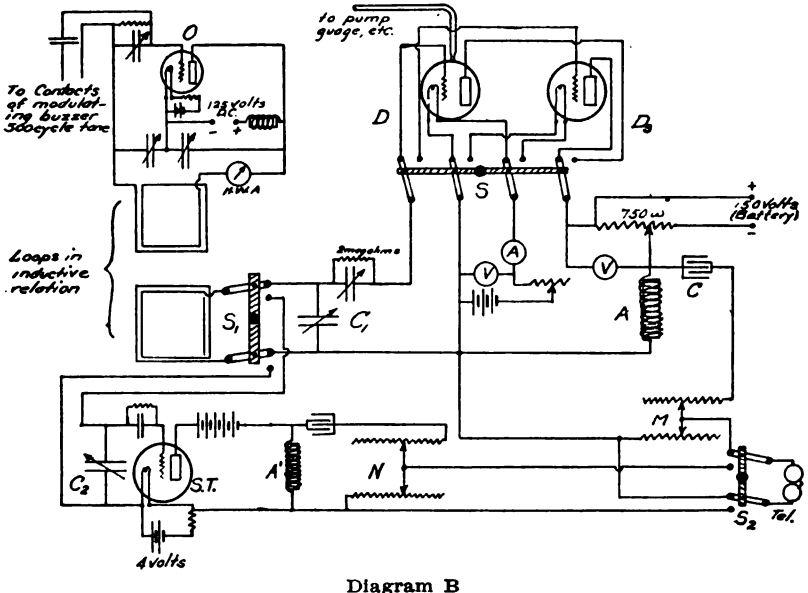

Diagram B
Standard Circuit for Audibility and Intensity Comparison Tests.

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neon, helium, argon and carbon dioxide were used. Nitrogen, neon, air, and carbon dioxide gave about the same degree of signal response, argon gave 25 to 50 percent louder response, helium gave a slightly weaker response, and hydrogen a very weak response. It was found that adjustments of plate voltage and filament current were critical for all gases to the same degree except for helium. Helium filled tubes are less critical as regards plate voltage and filament current adjustment. Critical characteristics of plate voltage adjustments for various pressures and gas content are shown in Fig. 2.

Referring again to Fig. 1 it will be noticed that for very low degrees of vacuum the "operating voltage" approaches the ionizing potential of the gas in the tube. For nitrogen, hydrogen, or neon, it is about 18 volts, but for helium about 25 to 28 volts, which values represent the values of ionizing potentials for these gases. Accordingly, it should be possible to introduce a gas having a very low ionizing potential, and thus have a tube requiring a low operating voltage. Mercury vapor was introduced, and it gave an operating voltage of 14 or 15 volts. (Note that the ionizing potential of mercury vapor is 10.5 volts.) A small amount of mercury was put into two tubes, and after being pumped out and sealed off the pressure of mercury vapor pressure could be varied by varying the temperature of the tube walls. For best results the mercury vapor pressure was that corresponding to a temperature of about 25° C. At temperatures of 50° or 60° C the adjustments become very critical; at 25° C these tubes showed about 50 percent increase in audibility over good vacuum tubes. This seemed to indicate that certain metallic vapors would be desirable if the vapor pressure did not become too great when the tube walls were hot.

Recently this latter phase of the problem was again taken up, and three of the alkali metals were introduced into detector tubes. The vapors of potassium-sodium alloy, rubidium, and caesium have ionizing potentials of four volts and less. Potassium-sodium alloy in a liquid state similar to mercury was introduced without expos-

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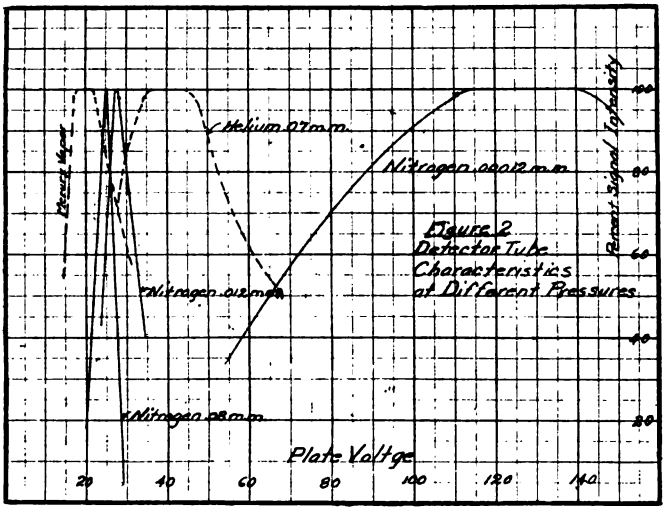

ure to air into several tubes by a laborious process. Rubidium, being somewhat sticky, was somewhat harder to introduce. The potassium-sodium filled tubes seemed to give some remarkable results, whereas rubidium tubes seemed worthless, on account of extremely high plate resistance. Accordingly, several tests were made on the potassium-sodium content tubes. Figs. 3 and 4 show plate current grid voltage curves for various plate voltages from zero up to 120 volts. It will be noticed that for low plate voltages curves are similar to those of a *vacuum* tube, and that as plate voltage increases, the bend at the point of saturation flattens out until at 120 volts the curve is a straight line from −12 volts grid potential to +12 volts grid potential. This would indicate that the tube might be a good amplifier. The curves of Fig. 5 show this to be the case. Each curve of this set is obtained with constant plate current, hence u, the no load amplification constant, is the negative slope of the plate voltage grid voltage characteristic. (See Van der Bijl or Morecroft). The curves of Fig. 5 indicate that these tubes are similar to high vacuum amplifiers as regards variation of amplification constant and the slope indicates a high value for u, about 10 to 12. The dotted curve A of the figure is typical for low vacuum tubes containing air, nitrogen, hydrogen, helium, etc., and B

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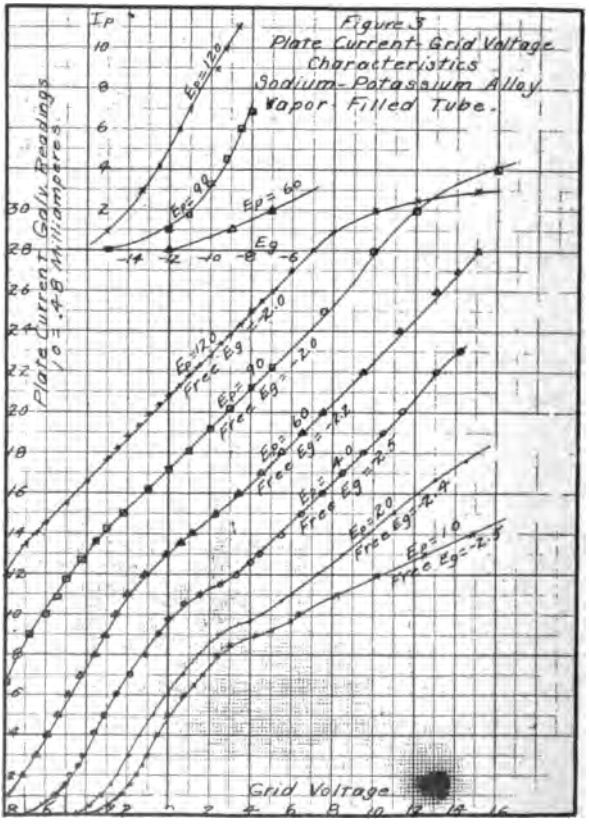
for high vacuum amplifiers. Figure 6 shows grid current characteristics for the same tube as used in obtaining curves of Fig. 4. For negative grid voltages there is no negative grid current, which is not the case for some high vacuum tubes. The curves increase suddenly at about -2 volts grid potential which indicates good de-



tecting characteristics. It should be mentioned that the detecting efficiency depends greatly upon the assymetry or variation of the slope of this curve. (See page 456, "Principles of Radio Communication" by Morecroft.) If the grid were connected to the positive end of the filament, the grid current would rise at zero grid voltage instead of at -2 volts, but its slope would be the same. To show how the tube constants vary with plate voltage the

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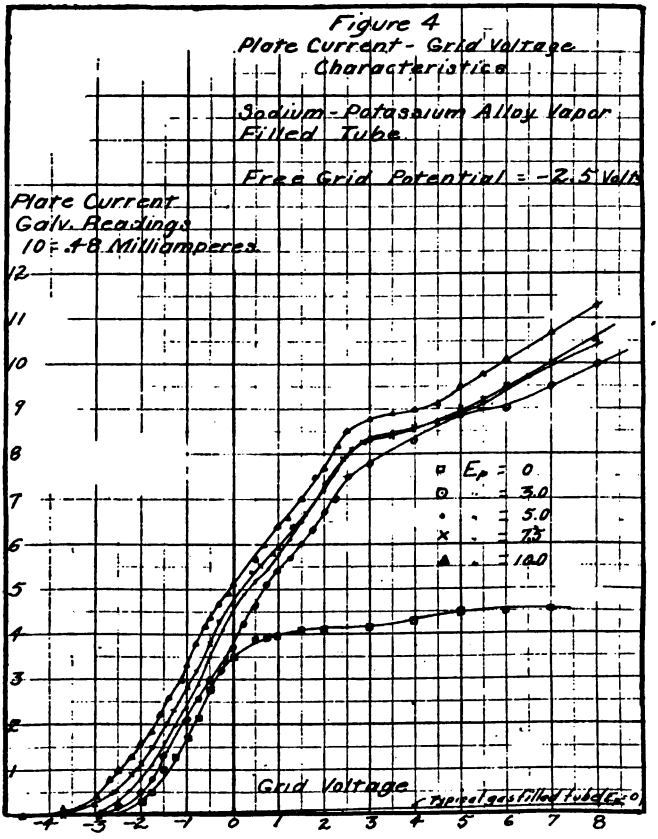
mutual conductances and amplification constant of three of these tubes were measured by Van der Bijl's methods for varying plate voltages and the results plotted in Figs. 7 and 8. It should be noticed that the mutual conductance is high for low plate voltages and falls off gradually (See Fig. 7) as plate voltage increases. This constant increases gradually with filament temperature. The sam-



ple curves A and B of Fig. 7 show the variation of this constant for gas content tubes and high vacuum tubes respectively. For a discussion of mutual conductance see Van der Bijl, "The Thermionic Tube". It is usually the case that the tubes with high values of this constant are good detectors, although they should also have high amplification constants and large change in the slope of the

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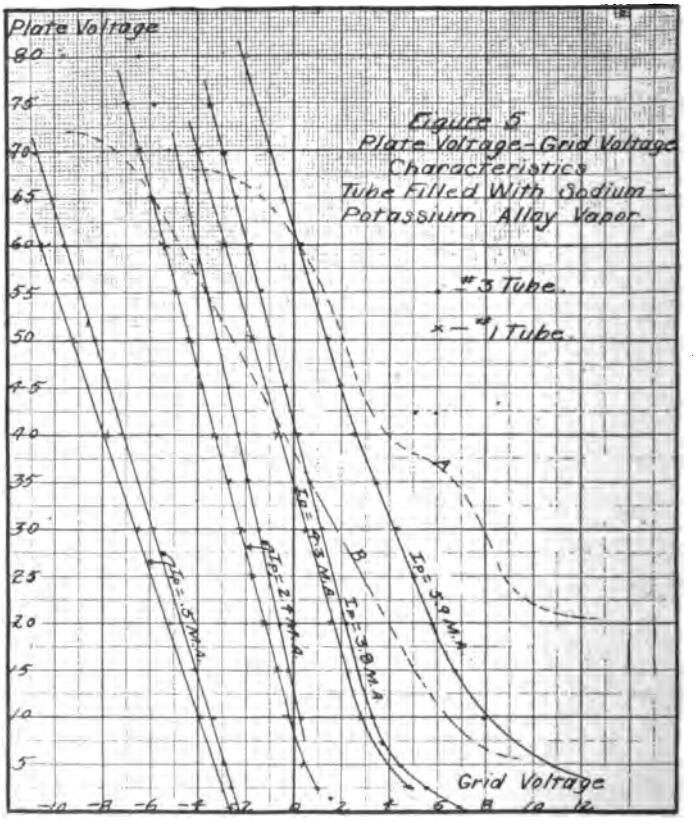
grid current curve. Fig. 8 is very interesting as it shows that the potassium-sodium content tubes have high amplification constants even at high plate voltages, but that they would function best as amplifiers at about 6 to 10 volts on the plate. The curves A and B, typical for gas filled and vacuum tubes, should be noted for comparison. Fig. 9 shows how the potassium-sodium tubes be-



have as detectors with varying plate voltages. Comparing these curves with those of Fig. 2 it will be noticed that the tubes containing potassium-sodium alloy are quite remarkable. The best signal response is for plate voltages of from 8 to 10 volts, or less than half of that necessary for gas filled tubes, while they are much less critical than the latter, and give good audibility at 40 volts

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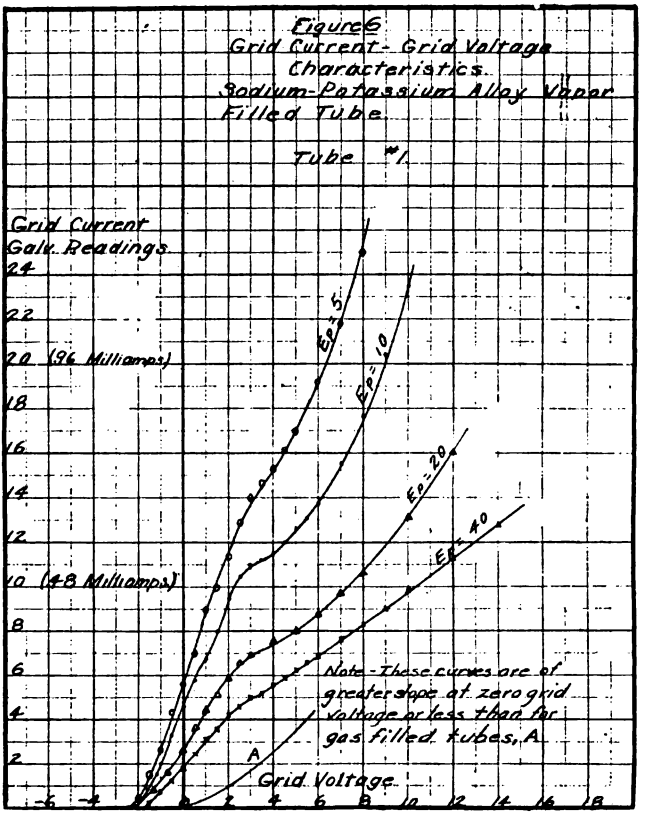
or more on the plate. The variation of signal intensity with filament current is like that for high vacuum tubes, the intensity gradually increasing until the filament is at very high temperature, and then gradually decreases. The maximum received signal intensity seems to be from 3 to 5 times as great as for the same type of tube filled



with argon or neon. This comparison was carefully made and results were practically the same for the three tubes tested.

In all of the tests a variable grid condenser was used in series with the grid together with a grid leak of 2 megohms. This always gave at least as good audibility as any applied negative grid potential, except for mercury vapor filled tubes, in which a positive grid potential was used.

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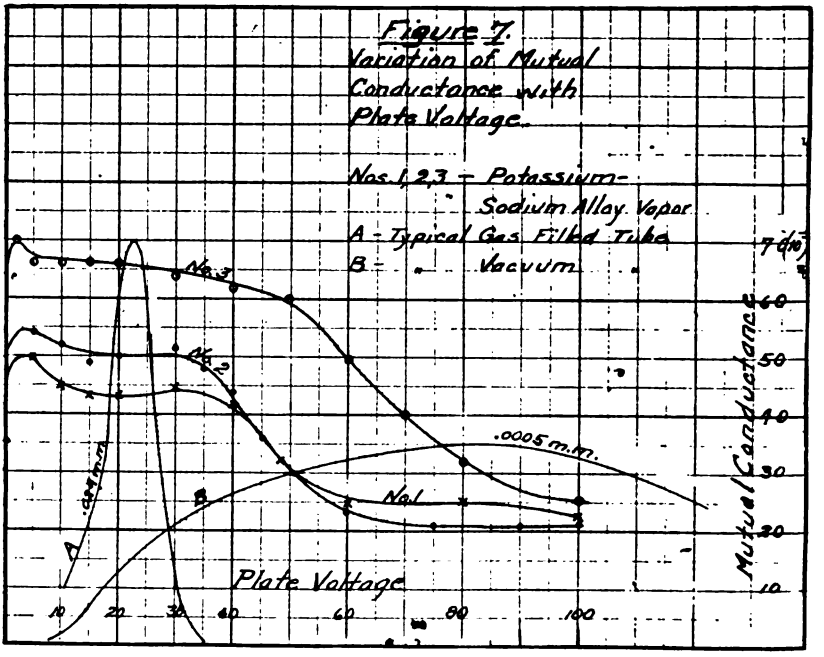
The above test, being quantitative, was fairly conclusive proof that the potassium-sodium alloy content tubes are superior to the gas filled or vacuum detectors. However, to be sure as to their practical utility, the tubes were placed in standard receivers to receive the 2500 meter spark station at Arlington, the 17000 meter station at Annapolis, and the 360 meter radiophone broadcasting stations at Pittsburgh, Schenectady, N. Y., Detroit, and Chicago. The results obtained were consistent with the quantitative measurements. For receiving



the radiophone stations the tubes were used as oscillating detectors by the "zero beat" method, and also by the heterodyne method for the 17000 meter station, and the writers and their assistants were astonished at the results. Speech and signal reception were remarkably loud and distinct, and with practically no need of any frequent readjustments, as are often necessary with gas filled tubes. The tubes even functioned fairly well as oscillating detectors with zero plate voltage, receiving the above stations. They were also used as amplifiers

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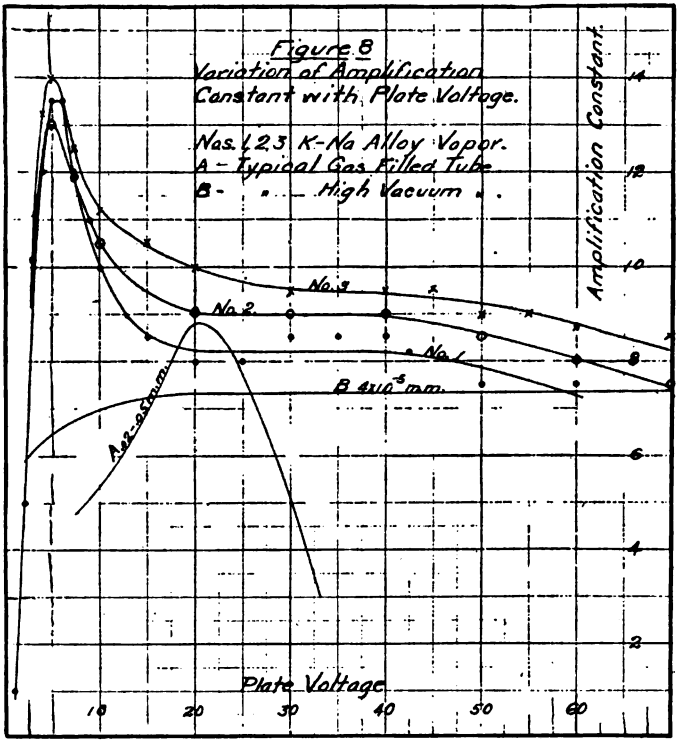

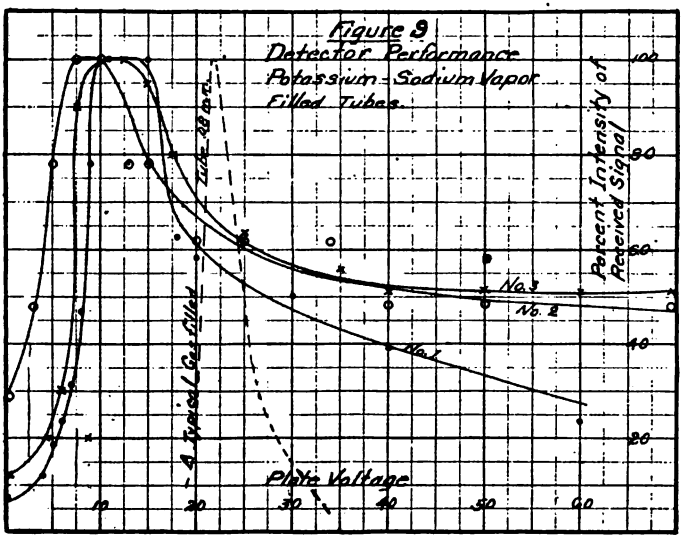

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in these same circuits and gave louder and clearer speech amplification with six volts on the plate than did the vacuum amplifier tubes with 30 or 40 volts.

The potassium-sodium alloy is used for the sensitive coating in the photo-electric cell, and it seems certain that the resulting plate current with zero applied plate voltage is due to the photo electric effect of the light from the incandescent filament. The plate current, and also the detector action at zero plate voltage, were maintained when the return plate circuit was connected to either the negative or positive terminal of the filament, indicating that the result was not due to potential drop along the filament.

CONCLUSION

Investigation of the action of the various gases mentioned in detector tubes shows that if inert gases are used the pressure should not exceed .005 mm. of mercury for best results as regards sensitiveness and non-critical adjustments. If certain metallic vapors are used, low "operating plate voltages" may be used if the ionizing potential of the vapor is low, and the tubes will be still more sensitive and much less critical in adjustment than low vacuum tubes containing an inert gas. The sensitiveness increases with the atomic weight of the gas in the tube, or more probably with the number of free electrons in the gas atom. It is hoped that further investigation will show some other gas or metallic vapor to be still better than the ones discussed in this paper. The potassium-sodium alloy and rubidium were kindly furnished by Dr. Jakob Kunz. Dr. Kunz recommended these substances in response to an inquiry as to what gases had very low ionizing potentials. Acknowledgment is also due Mr. W. E. Davis, a senior student, for his faithful assistance in the work.

Laboratory of Physics
University of Illinois
April 21, 1922

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THE INFRA-RED ABSORPTION OF SOME OXIDES OF NITROGEN

B. J. Spence, Northwestern University

The following is intended merely as a preliminary report of work taken up in an attempt to add to the data bearing upon the considerable theory already developed for the infra-red absorption of gases made up of simple molecules. The theory in the case of a simple diatomic gas assumes that the molecule is made up of two atomic nuclei separated by only a short distance. These nuclei are held together by a ring of electrons rotating about an axis joining the two nuclei and between them. According to the quantum theory it is possible for a molecule to rotate about an axis at right angles to the line joining the nuclei with definite but different velocities. If the moment of inertia does not change, these different velocities of rotation will manifest themselves as simple absorption bands in the far infra-red region. If, on the other hand, isotopes of one of the atomic nuclei exist, there will be different moments of inertia of the molecule. The different moments of inertia will not differ greatly and instead of a series of simple bands, we shall find a series of more complex bands, for example, triplets, where two isotopes of one of the nuclei exist.

If the nuclei vibrate along the line joining their centers with a simple harmonic motion, the vibration will manifest itself as an absorption band in the near infra-red region. This frequency of vibration may combine with a rotation frequency to produce a series of bands in the region of the vibration frequency. If the vibration frequency is not simple harmonic on account of large nuclear displacements, such a vibration will give rise to harmonics whose frequencies are approximate multiples of a fundamental frequency. These in turn may combine with the rotation frequencies to produce the complicated system of bands in the region of the harmonic frequencies. In short, there should be rotation frequencies, vibration frequencies, harmonic frequencies, and combination frequencies. These, however, need not

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necessarily all be manifested as absorption bands in a single gas.

The evidence supporting such a theory is very meager, and this investigation was undertaken in an attempt to add more data to the general problem. Accordingly the absorption of NO, NO_2, N_2O_4, and N_2O was investigated by means of a grating spectrometer and a radiometer in the region from 1 u to 4.5 u. A large number of new bands was found in each case in this region. No attempt has yet been made to apply the theory which has already been developed.

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THE ACTION OF LIGHT UPON ARSENIC TRISULFIDE HYDROSOL

RAY V. MURPHY, ILLINOIS WESLEYAN UNIVERSITY

In the course of some experiments upon the conductivity of mixtures of electrolytes and colloids it was observed that the conductivity of a carefully prepared arsenic trisulfide hydrosol was gradually increasing, the increase being most pronounced during those periods when the lamp of the thermostat remained lighted. It was finally decided that the heating lamp was the source of the disturbance, the reaction in the sol being a photochemical one. Tests were made by exposing some of the sol in the conductivity cell to the light of a 500 watt, nitrogen-filled lamp placed about 60 cm. from the cell. A marked increase in the conductivity resulted. The investigation was then extended to a study of the change in the conductivity of the sol of various dilutions when exposed to the light of the lamp under uniform conditions of temperature and intensity of illumination.

PREPARATION OF THE SOL

One liter of a solution of H_2S, prepared by saturation of ice-cold freshly boiled distilled water, was added slowly, with constant stirring, to one liter of As_2O_3 solution containing two grams As_2O_3. The resulting clear sol was then boiled for about six hours to remove excess H_2S, the boiling being done in a darkened room. A portion of the water was allowed to evaporate until a sol containing about 4.5 grams As_2S_3 per liter was obtained. The resulting sol was faintly milky by reflected light, but clear by transmitted light. It was allowed to stand 48 hours. This is taken as the "100% sol". Samples containing 75%, 50%, 25%, 12.5% and 5% of the original sol were also prepared by dilution of the 100% sol with "conductivity" water of specific conductivity 1.1×10^{-6}. All samples were allowed to stand two weeks to age before the studies were made.

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ANALYSIS OF THE SOL

The analysis of the 100% sol gave the following data:

Arsenic per liter	2.9080 g.
As_2S_3 per liter (calculated from As)	4.7737 g.
H_2S per liter	.1363 g.

METHOD

The conductivity cells were of special design, resembling small flat-bottom flasks of about 30cc. capacity, with the electrodes inserted in the sides. The procedures of filling the cells, transferring to the thermostat, etc., were conducted in the dark. The thermostat lamp was painted black and enclosed in black paraffined paper. The samples were exposed to the light of the 500 watt, concentrated filament, nitrogen-filled lamp mentioned above, placed at a fixed distance of about 60 cm. from the cells. Exposures to the light were made for definite intervals at constant temperature, the cells transferred to the thermostat, and the conductivities measured, using a special set-up consisting of a Wheatstone set built up from Curtis coils and a Leeds and Northrup drum-type Kohlrausch slide wire, with air condensers for obtaining proper phase balance. The energizing current was at 1200 frequency and was generated by an audion oscillating circuit, the bridge balance being accurately determined by the use of a DeForest P-200 two-step audion amplifier, using special high-resistance telephones. The point of balance was one of complete silence, the slightest movement of the contact of the 4.7 meter Kohlrausch slide wire to right of left giving a distinctly audible sound. The set-up was built along lines suggested by Hall and Adams.[1)]

DATA

The data of the determinations are given in the Table. The curves were constructed from the same data.

DISCUSSION OF THE DATA

It will be observed that the curves for the different concentrations are nearly parallel, thus showing that the

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rate of change in the conductance was practically the same for the sols of different initial concentrations. However, on closer examination of the curves for the sols of different concentrations, it will be seen that the slopes at corresponding times increase as the concentration of the sol diminishes. Thus for the eight and sixteen hour periods the slopes are approximately as follows:

	Slopes of the curves for					
Time	100% Sol	75% Sol	50% Sol	25% Sol	12.5% Sol	5% Sol
8 hours	.600	.581	.675	.750	.725	.781
16 hours	.375	.372	.453	.522	.519	.578

These figures indicate that the rate of change of conductance increases with decreasing concentration of the sol. The slope of each of the curves gradually becomes smaller, and all the curves would eventually become parallel to the time axis and further increase in conductivity cease if the runs were continued for a sufficient length of time. It was observed that a finely divided whitish

TABLE OF DATA.

	Specific Conductivity, $K \times 10^{-5}$		
Time in Hours	100% Sol	75% Sol	50% Sol
0	18.127	15.333	10.943
.0833	18.209	15.413	11.032
.2500	18.444	15.568	11.145
.5833	18.814	15.918	.....
1.0833	19.265	16.358	12.008
2.0833	20.199	17.234	13.004
3.0833	20.750	17.911	13.799
4.5833	21.746	18.750	14.809
6.5833	22.564	19.584	15.867
9.5833	23.160	20.294	16.717
15.3833	24.069	21.281	18.097
	25% Sol	12.5% Sol	5% Sol
0	6.898	4.983	2.715
.2167	7.129	5.204	2.930
.6500	7.577	5.620	3.333
1.3167	8.279	6.281	3.953
2.8167	9.445	7.802	5.372
5.8167	11.786	9.652	7.250
11.0667	13.876	12.036	9.874
14.6670	14.934	13.027	11.223
18.0000	15.952	13.741	12.220

precipitate formed on the bottom of the conductivity cells in all cases.

Freundlich and Nathansohn[2)] have pointed out that the gradual clouding and final precipitation of sulfur followed by coagulation of arsenic trisulfide from a care-

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fully prepared, clear arsenic trisulfide hydrosol may be explained upon the following grounds: Arsenic trisulfide hydrosol sensitizes the photochemical oxidation of dyestuffs like eosin and malachite green. Due to this photosensitizing action of the arsenic trisulfide micelles, hydrogen sulfide produced by the hydrolysis of arsenic trisulfide is oxydized to colloidal sulfur which is stabilized by absorbed pentathionic acid. That pentathionic acid is the stabilizing electrolyte for sulfur hydrosols of the Oden type, has been shown by Freundlich and Scholz[3]. This acid is quite stable in the presence of hydrogen sulfide, with which it reacts to form free sulfur and water:

$$5\ H_2S + H_2S_5O_6 = 10\ S + 6\ H_2O,$$

this reaction explaining the great sensitiveness of the Odén S-hydrosols toward H_2S. It is the reaction between the stabilizing pentathionic acid of the S-micelles and the stabilizing H_2S of the arsenic trisulfide-micelles according to the above equation which deprives the micelles of both sols of their stabilizing electrolyte and results in the coagulation of a mixture of the two sols.

In their presentation of the above explanation of the action of light upon arsenic trisulfide hydrosol, Freundlich and Nathansohn do not discuss the mechanism of the formation of pentathionic acid. It is probable, however, that the photochemical oxidation of H_2S which results in the formation of colloidal sulfur may also account for the formation of the pentathionic acid, presumably by the photochemical oxidation of H_2S to SO_2 which reacts with H_2S to form the acid, a reaction which is probably one of many taking place in the formation of Wackenroder's solution, and which has been investigated by Debus[4] and others:

$$5\ H_2S + 15\ O = 5\ SO_2 + 5\ H_2O$$
$$5\ H_2S + 5\ SO_2 = H_2S_5O_6 + 5\ S + 4\ H_2O$$

Assuming that a condition of equilibrium exists in an arsenic trisulfide hydrosol with respect to adsorbed hydrogen sulfide and pentathionic acid on the one hand, and intermicellular hydrogen sulfide and acid on the

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other, the action of light would be merely to maintain the equilibrium by the formation of pentathionic acid and colloidal sulfur as the reaction between H_2S and the acid proceeds.

With certain assumptions regarding the mechanism of the above process the explanation offered by Freundlich and Nathansohn can be reconciled with the fact that the conductivity of the sol increases upon exposure to light. If the process resulted in the reaction between the first traces of pentathionic acid formed and H_2S, the conductivity of the sol could not increase, since no substance of sufficiently high conductivity is formed to account for the changes produced. On the other hand, if the formation of S-hydrosol, whether by the photochemical oxidation of H_2S or by the H_2S-pentathionic acid reaction, is assumed, a gradual increase in conductivity can be more readily explained. Colloidal sulfur produced by either or both of these reactions will adsorb pentathionic acid as stabilizing electrolyte, the S-micelles, with their adsorbed acid, serving to augment the conductivity of the solution, and maintaining at the same time a certain concentration of free acid in the intermicellular liquid by virtue of the adsorption equilibrium set up. Both of these factors serve to increase the conductance. Eventually the concentration of the intermicellular pentathionic acid will reach such a value that the rather slow reaction of the acid with intermicellular H_2S, which has been increasing in speed with continued increase in the concentration of the acid, will proceed unhampered, an equilibrium having thus been set up between the various components of the system. The attainment of this equilibrium marks the end of the increase in the conductivity of the sol.

The fact that the rate of change of conductance increases with decrease in the concentration of the sol is readily explained in view of the work of several investigators who have pointed out that dilution of a sol results in increased dispersion, i. e., diminution of the size of the particles. Increased dispersion of the colloid particles will favor the speed of the reaction due to the increased photochemical activity of the micelles per unit

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mass of As_2S_3 owing to the relatively greater active surface.

In the above discussion of the mechanism of the reaction it is assumed that the H_2S-pentathionic acid reaction proceeds only in the intermicellular liquid, and not in the adsorbed layer enveloping the As_2S_3 particles, since it is taken for granted that As_2S_3 and S-micelles, respectively, retain the H_2S and pentathionic acid adsorbed as stabilizing electrolyte, out of the sphere of reaction with each other. The photochemical formation of colloidal sulfur and pentathionic acid takes place only in the adsorbed layer.

It is noteworthy to remark that the photochemical reaction is not reversible, samples of the sol which had been exposed to light suffering only a very slight decrease in conductance on being kept in the dark for periods as long as several days. This slight decrease in conductance is explained as being due to the fact that the slow H_2S-pentathionic acid reaction, which in itself tends to lower the conductance by formation of H_2O and S from the active electrolyte, pentathionic acid, continues for some time after the action of light ceases, the resultant effect being a slight diminution of the concentration of the intermicellular pentathionic acid.

There may be some question as to the nature of the electrolyte formed in the photochemical process. The fact that Freundlich and Scholz have demonstrated the existence of pentathionic acid in colloidal sulfur is not to be taken as *a priori* evidence of the existence of the same stabilizing acid for the colloidal sulfur formed in As_2S_3 hydrosol. Whether the acid formed is pentathionic, tetrathionic or another of the thionic acids known to exist in Wackenroder's solution, or a mixture of two or more members of the family, is conjectural. It would seem more plausible, possibly, to assume the formation of tetrathionic acid, since this is undoubtedly the first product formed in the preparation of Wackenroder's solution.

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SUMMARY

1. The electrical conductivity of arsenic trisulfide hydrosol increases upon exposure to light, the rate of increase being practically independent of the initial concentration of the sol, although increasing somewhat with decreasing concentration of the colloid. Studies were made upon a very pure arsenic trisulfide hydrosol (one containing very little excess hydrogen sulfide), following the conductivity during exposure to the light of a 500 watt nitrogen-filled lamp under constant conditions of temperature and intensity of illumination.

2. The reaction is explained, after the suggestion of Freundlich and Nathansohn, as one of a two-stage photochemical oxidation of H_2S adsorbed on the As_2S_3-micelles to colloidal sulfur and pentathionic acid (or tetrathionic), followed by the reaction between H_2S and the thionic acid in the intermicellular liquid with liberation of free sulfur, and with final precipitation of As_2S_3 upon removal of the stabilizing H_2S. The increase in conductivity is to be explained as due to the building up of a concentration of the thionic acid more than sufficient to serve as the stabilizing electrolyte for the colloidal sulfur, the reaction with H_2S then proceeding at such a rate that the equilibrium is maintained between the several components of the system, further change in conductance thus being prevented. The increase of the rate of change of the conductance with decreasing concentration of the sol is explained as due to the increased photochemical activity per unit mass of As_2S_3, brought about by the greater dispersity of the more dilute colloid.

The author wishes to acknowledge the kind assistance of Dr. J. H. Mathews of the Department of Chemistry at the University of Wisconsin, under whose direction the work described in this paper was done.

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1) Jour. Am. Chem. Soc. *41*, 1515, (1919).
2) Koll. Zeit., *28*, 258, (1921).
3) cf. Freundlich and Nathansohn, loc. cit.
4) Jour. Chem. Soc. 53, 278, (1888).

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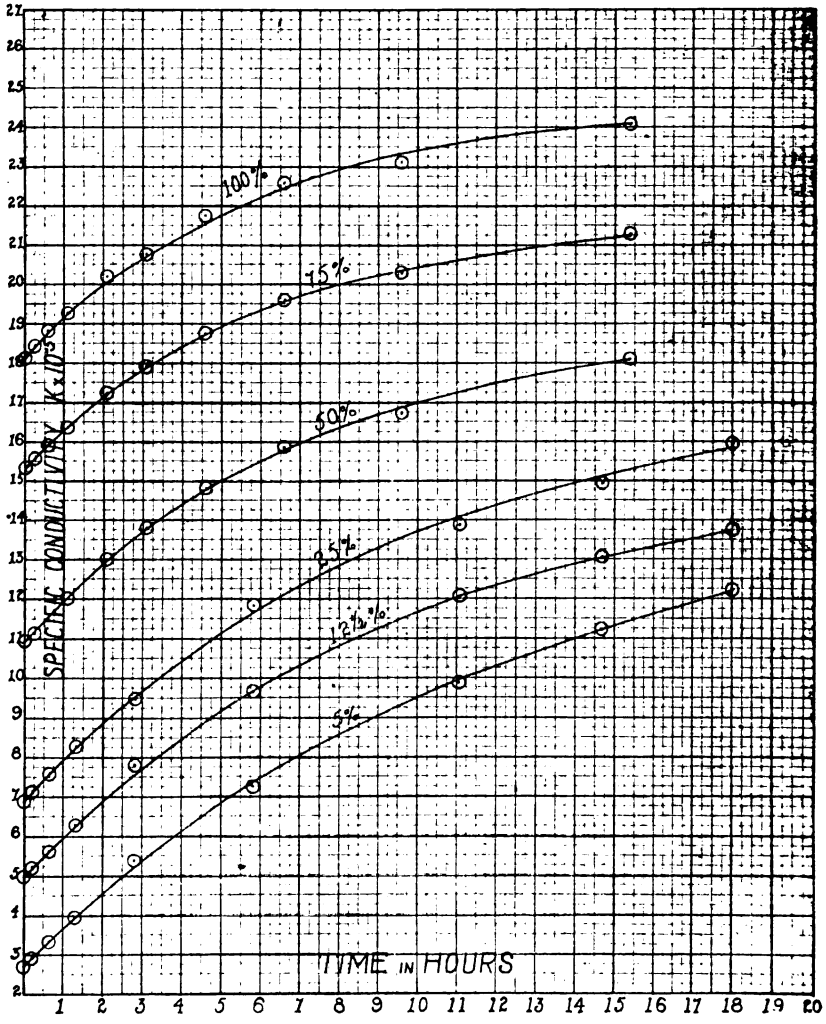

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THE DETERMINATION OF "g"

A. C. LONGDEN, KNOX COLLEGE

It is not the object of this paper to present a new method or even to consider exhaustively the older methods of determining "g". That would require more time than I have at my disposal. What I hope to do is to indicate a way of getting better results from one of the well known methods.

Of the various methods of determining "g", the simple pendulum method is doubtless the most widely used, and perhaps, all things considered, the most generally satisfactory.

I think it is the method which succeeds best in the hands of our students, and I also think it has within it the possibilities of great precision.

The quantities to be measured are two in number, the length of the pendulum, l, and the period, or half period, t, in the formula $g = \frac{\pi^2 l}{t^2}$

The length of a pendulum about a meter long can easily be measured to within one part in ten thousand, with a good cathetometer, if the pendulum is properly constructed, and if suitable corrections are made for the mass of the suspension and for the moment of inertia of the ball. If, then, the period can be determined with equal accuracy, we should have no difficulty in getting the fourth figure in the final value of "g".

The period, however, must be *squared* and must therefore be determined to within one part in twenty thousand, in order that the value of "g" may be correct to within one part in ten thousand.

To count twenty thousand oscillations and guarantee the count would be rather too great a strain on human endurance, even if we could get a pendulum to continue swinging long enough, which would be another difficulty.

The coincidence method furnishes a perfectly splendid way of supplementing human endurance at this point, but our next difficulty lies in the fact that the oscillations

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are not strictly isochronous. Many of our laboratory manuals say they are practically so, if the amplitude of the pendulum is not more than five degrees. Well, that might do for measuring t to within one part in a thousand, but not for one part in twenty thousand.

Figure 1 shows the interval between coincidences on the Y axis, plotted against the number of intervals between coincidences on the X axis. It is obvious that as the number of intervals increases, that is, as the amplitude of the pendulum decreases, the length of the interval decreases.

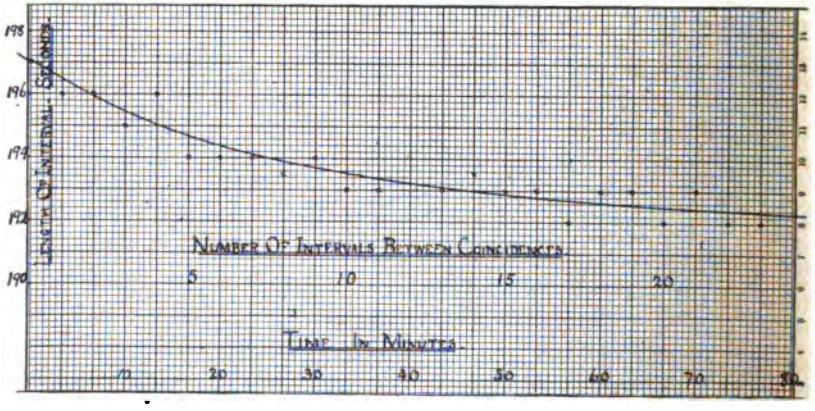

Figure 1.

This is a case in which a pendulum a little less than a meter long ran an hour and twenty minutes, starting with an amplitude of 46 mm. and finishing with an amplitude of 3.5 mm.

During this time the interval between coincidences decreased from about 197 seconds to about 192 seconds. Which value shall we accept? Neither of them, of course. The period is changing with the amplitude, and we really want the period for an infinitesimal amplitude. However, the interval between coincidences approaches a minimum as the curve approaches a position parallel to the X axis. The curve appears to be nearly horizontal

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at the end of the twenty-fourth interval, but just how much farther it has to run, it would be difficult to say.

Figure 2 shows the decrement in amplitude for the same set of observations. The two curves are quite similar in character.

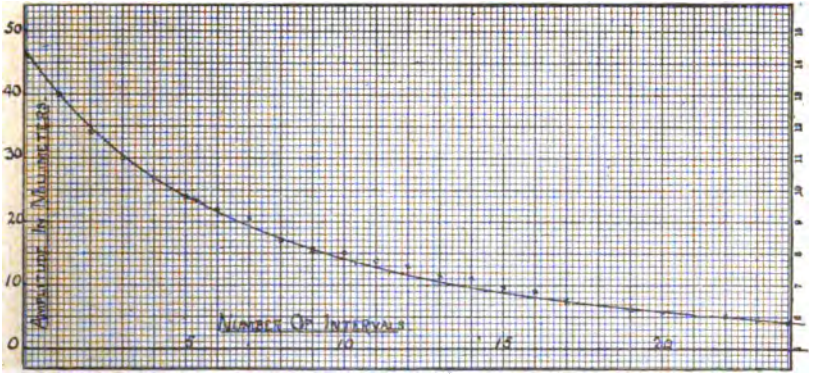

Figure 2.

In figure 3 they are plotted on the same scale, and when the two are placed side by side they are seen to be almost identical.

It is obvious that the interval approaches a minimum as the amplitude approaches zero. That is, when the curves are drawn on the same scale, the minimum on the interval curve may be taken at the X axis on the amplitude curve. In this case, the amplitude curve is two

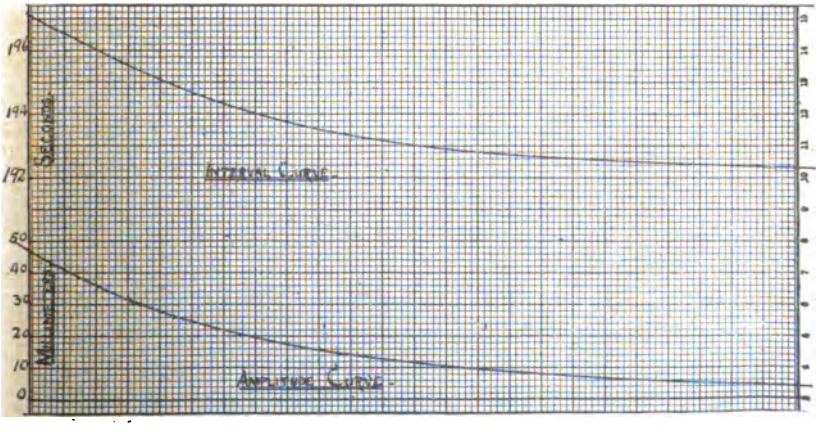

Figure 3.

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spaces above the X axis at the end of the twenty-fourth interval. Since the two curves are so nearly identical, we may safely assume that the interval curve reaches a minimum two spaces below its position at the end of the twenty-fourth interval. This would be about 191.9 seconds, and with no very great uncertainty about the fourth figure.

Granting the possibility of an error of one or two units of the fourth order, let us see what the effect would be on the period.

For an interval of 191.9 seconds, the period is 191.9 divided by 192.9, or, .994816 if carried to the sixth figure. For an interval of 191.8 seconds, the period is 191.8 divided by 192.8, or, .994813+, and likewise for an interval of 191.7 seconds, the period is .994811—.

There is, of course, no justification for carrying these results to six figures; but the calculation shows that if the curve can be placed correctly to within one or two, or even to within three or four spaces on the chart, the period is correct to five figures.

These results are alike to within considerably less than one part in twenty thousand.

Our measurements, then, are sufficiently exact, and we might expect results within one part in ten thousand, if there are no other sources of error.

There is, of course, a formula which corrects the period of a pendulum for the amplitude, but who can say what other errors are to be corrected? For example, does the suspension bend exactly at the edge of the clamp which holds it, or does it begin to bend a little farther down? And, if the suspension is very slender, does the weight of the ball stretch the wire more when moving at a higher velocity than when moving at a lower velocity, and if so, how much does that add to the length of the pendulum?

These questions are important if the pendulum is swinging through an appreciable arc, but they lose their significance entirely when the pendulum is swinging through an infinitesimal arc, and therefore, errors arising from such sources are eliminated entirely by the

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method here described of finding the minimum interval between coincidences.

Finally, when all the errors are included in measuring both the length and the period of the pendulum, in the hands of our students in Knox College this method yields results ranging from 980.2 to 980.4.

The theoretical value of "g" for Galesburg is 980.26.

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A METHOD OF MAGNIFYING SMALL ANGULAR DISPLACEMENTS

RALPH C. HARTSOUGH, ILLINOIS WESLEYAN UNIVERSITY

OUTLINE AND SUMMARY

1. Basic principle is multiple reflection
II. Limits of range
    (a) Theoretical
    (b) Practical
III. Experimental data and conclusions.

SUMMARY

By multiple reflection between two parallel mirrors, an incident ray is turned through a magnified angle upon emerging provided one or both of the mirrors are turned slightly. The amount of magnification depends on the number of reflections. Theoretically the limits of operation are much greater than are possible from a practical standpoint, for on account of absorption, the incident ray after many reflections becomes a very weak emergent ray. However, with mirrors of high reflective power, and by taking advantage of moving both mirrors, a magnification of one hundred is easily obtainable.

I. BASIC PRINCIPLE IS MULTIPLE REFLECTION

The author was confronted with the problem of measuring some very small angular displacements, and devised an optical method which he chose to call "The angleometer". A beam of light is reflected back and forth between two parallel mirrors as in Figure I. If either or both of the mirrors are turned through a small angle, the emergent ray will be turned through an increased angle depending upon the number of reflections of the turning mirror.

In Figure I, the illustration shows the short mirror stationary, and the long mirror turning through a small angle. The number of reflections on the movable mirror multiplied by two gives the magnification number. A reflected ray from a mirror is turned through twice the

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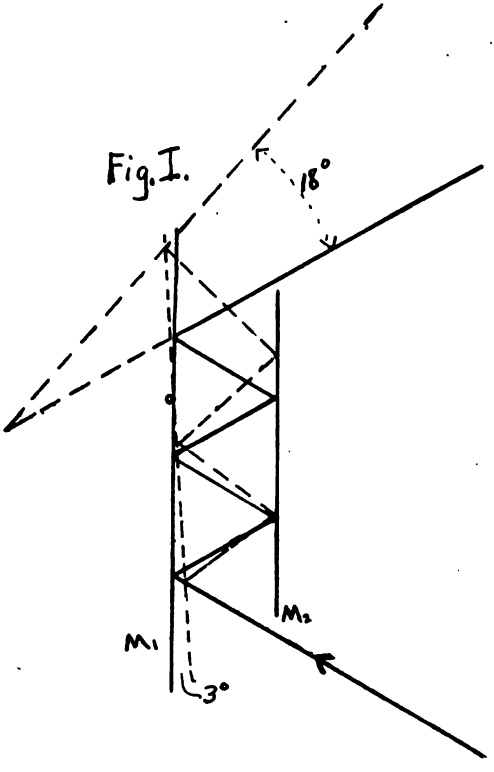

angle that the mirror is turned. The magnification is increased by increasing the number of reflections and by turning both mirrors in opposite sense. It is evident that in Figure I if the short mirror had turned an equal amount in the opposite sense to the long mirror, we would have increased our magnification.

II. LIMITS OF THE RANGE OF "THE ANGLEOMETER"

The nearer to the perpendicular the incident ray is brought, the greater the number of reflections, and the greater the magnification. But on account of the absorption of the mirror with each reflection, we are limited in the number of reflections. With a mirror of 95% reflective power, and allowing 50 reflections, there would about 10% of the light get through as the emergent ray. This is not an impossibility, for with a very intense source and an emerging ray one-tenth the intensity as

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the incident ray, it is readable to a good degree of accuracy.

EXPERIMENTAL DATA AND CONCLUSIONS.

Number of moving reflections N	Angle mirror moved A	Angle emergent ray moved B	$\frac{B}{A}$	N x 2
7	0.06°	0.86°	14.3	14
9	0.05°	0.95°	19.0	18
11	0.042°	0.93°	22.1	22

By utilizing the optical lever, the emergent ray is converted into a measurable quantity even with .0001° angular displacement of the moveable mirror, using eleven reflections.

By using the two mirrors on moveable systems, an angular displacement of .00005° can be measured.

CONCLUSIONS

One-fifth of a second of arc is measurable with high precision by this method, and it seems not an improbability to refine it to measure much smaller displacements.

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THE VAPOR PRESSURE AND HEAT OF VAPORIZATION OF NON-ASSOCIATED LIQUIDS.

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In the application of physico-chemical principles to industrial and manufacturing processes, few questions are of more frequent occurrence than those dealing with distillation problems. The questions take a variety of forms, but most of them may be answered when the vapor pressures of the substances involved are known. Occasionally the desired information may be found in, or calculated directly, from data given in the literature. More commonly this is not the case, and it is then necessary either to make the measurements directly or to resort to some method of calculation of the required data.

Many expressions have been developed for calculating vapor pressures and heats of vaporization, probably the most useful of which is that obtained from the integration of the Clausius-Clapeyron equation. Assuming the gas laws to apply and also assuming that the heat of vaporization is a constant throughout the desired range, and introducing common logarithms, there is obtained the expression:

$$\text{Log } P = \frac{-L}{4.58\ T} + C, \qquad (1)$$

in which P is the vapor pressure and T is the absolute temperature at which P is measured. C is an integration constant, the value of which depends upon the units used.

Equation (1) indicates that if the common logarithm of the vapor pressure be plotted against the reciprocal of the absolute temperature, a straight line should result. In view of the rather bold assumptions concerning the applicability of the gas laws and the constancy of the latent heat of vaporization, it is quite remarkable how closely experimental data may be represented by this linear equation throughout relatively wide ranges of temperature.

In equation (1) the term L/4.58 represents the slope of the log P vs 1/T vapor pressure curve. The integra-

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tion constant, C, is the value which log P would have when the temperature is some hypothetical maximum. Numerically, the value of C, assuming the pressure to be measured in mm. of mercury, varies from about 4.2 for helium to about 11.2 for tungsten. The exact value for any substance may be calculated when the latent heat and the boiling point at some particular pressure are known. The integration constant may be eliminated if the vapor pressures at two different temperatures are known. Equation (1) may then be transformed into:

$$\frac{\log P_2 - \log P_1}{1/T_2 - 1/T_1} = \frac{\triangle \log P}{\triangle (1/T)} = \frac{-L}{4.58} = \text{Slope} = S \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Thus it is evident that if the slope of the logarithmic vapor pressure curve be determined, the molecular latent heat of vaporization may be calculated, or vice versa.

Having shown that there is a simple expression for vapor pressures involving only two constants, the question naturally arises, Can these constants be evaluated from existing data? Since the slope of the straight line vapor pressure equation is directly related to the latent heat of vaporization (equation 2), and since the heat of vaporization is closely related to the normal boiling point as shown by the well known rules of Trouton[3], Nernst[5] and Bingham[4], it is probable that the slope, S, is a function of the normal boiling point, a constant which is known for many liquids.

In order to show the nature of this function we shall make use of the data collected in Table I. The data from which this table was constructed have been taken mainly from the Landolt und Boernstein, "Physickalisch Chemisch Tabellen" and the French Tables. For the vapor pressures of the metals, the most recent determinations of Ruff and Bergdahl[1] and of Langmuir[2] have been consulted as well. The vapor pressures of tungsten and platinum have not been directly determined above the melting point. Langmuir has determined the sublimation pressures, however, throughout wide ranges of temperatures. The values here given for the vapor pressures of these two metals have been calculated from the thermodynamic relations existing between the vapor

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pressure and the heats of vaporization, of sublimation and of fusion, in accordance with the principles discussed in a later section of this paper. The latent heat of fusion of tungsten is not known, but it may be shown that for most metals the molecular latent heat of fusion, expressed in small calories, is about 2.6 times the absolute melting temperature. The values used for making the calculations for these two substances are,

	M. Pt. (Abs.)	Ht. of sublimation	Ht. of fusion	Ht. of vaporization
Tungsten	3540	210,400	9200	201,200
Platinum	2028	123,500	5300	118,200

Under column 3, Table I, are recorded the slopes of the log P vs 1/T curves which have been determined from the experimental curves plotted on large scale coordinate paper. Now it is very evident that there is a gradual change in the slopes of the log P vs. 1/T curves as one passes from the substances having low normal boiling points to those having higher boiling points. This change is observed readily when the experimental slopes are plotted against the normal boiling points for these substances. The points on this plot lie very close to a line which may be represented by the equation:

$$S = -68 + 4.877\,T_b + 0005\,T\frac{2}{b} \qquad (3)$$

In this equation S is the calculated slope and T_b the absolute boiling point of the substance under normal pressure.

Under (4), Table 1, are given the slopes of the log P vs. 1/T curves calculated from equation (3), and in column 5 the differences between the observed and calculated slopes are recorded. It is quite evident, except at the very lowest temperatures where negative results are obtained, that this equation expresses the slope with a high degree of precision. Applied to the high boiling metals, the equation expresses the true slope with remarkable accuracy, the variations being both positive and negative. Indeed it may be said, that at all temperatures above 20° Abs., equation (3) expresses the true slope of

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TABLE I.

TAB

(1)	(2)	(3)	(4)	(5)	(6)
Substance	Tb	Sobs.	Scalc	Dif.	Lobs
Helium	4.3	5.8	−47	−52.8	.....
Hydrogen	20.2	50	45	−5	248
Nitrogen	77.3	314	315	1	1362
Oxygen	90.1	380	380	0	1630
Methane	108.8	440	463	23	.....
Phosphine	187.5	800	864	64	.....
Hydrogen chloride	190.0	900	870	−30	3860
Hydrogen bromide	205.0	920	950	30	3940
Hydrogen sulphide	211.5	1000	980	−20	4500
Hydrogen iodide	234.0	1150	1100	−50	4332
Chlorine	240.0	1080	1130	50	4650
Ethyl chloride	285.6	1310	1365	55	5760
Boron trichloride	291.2	1320	1400	80	5700
Isopentane	301.0	1400	1450	50	5870
Ether	308.0	1450	1480	30	6460
N-pentane	308.8	1470	1490	20	6180
Carbon disulphide	319.0	1450	1540	90	6380
Silicon tetrachlor	329.8	1580	1590	10	6350
Diisopropyl	330.5	1580	1600	20	.....
Bromine	331.6	1610	1615	5	6960
Chloroform	333.2	1620	1620	0	.....
N-hexane	341.6	1660	1660	0	6840
Phosphorous Trichlor	346.2	1690	1685	−5	7070
Carbon tetrachlor	350.7	1660	1710	50	7130
Benzole	353.3	1720	1720	0	7350
Hexamethylene	353.5	1720	1720	0	.....
Flourbenzole	358.0	1750	1750	0	7600
N-heptane	371.0	1800	1815	15	7590
Diisobutyl	382.2	1890	1870	−20	7990
Toluole	383.4	1880	1875	−5	7940
Stannic chloride	387.2	1890	1890	0	7900
N-octane	398.5	1970	1955	−15	8100
Chlorbenzole	405.0	1980	1980	0	8350
Propylene bromide	414.0	2050	2040	−10	.....
Brombenzole	428.5	2120	2120	0	8800
Trimethylene brom	437.4	2190	2160	−30	.....
Benzoic aldehyde	451.3	2320	2235	−85	.....
Iodobenzole	461.0	2250	2280	30	9430
Benzonitrile	463.6	2300	2300	0	9040
Benzoyl chloride	470.1	2380	2335	−45	.....
Nitrobenzole	485.0	2440	2420	−20	10050
Naphthalene	491.0	2460	2450	−10	10250
Chlornaphthalene	532.3	2675	2675	0	12100
Acenaphthene	550.5	2780	2770	−10	.....
Bromnaphthalene	554.0	2800	2795	−5	.....
Phthalic anhydride	556.5	2825	2800	−25	.....
Fluorene	570.5	2930	2880	−50	.....
Phenanthrene	611.0	3090	3100	10	.....
Anthracene	615.0	3120	3125	5	.....
Carbazol	624.0	3170	4170	0	.....
Mercury	630.0	3070	3200	130	13630
Sulphur	720.0	3700	3700	0	.....
Cadmium	1057	5750	5650	−100	23480
Zinc	1198	6880	6500	−380	25500
Antimony	1600	9000	9020	20	.....
Bismuth	1780	10100	10200	100	.....
Lead	1830	10200	10560	360	.....
Silver	2218	13150	13210	60	.....
Tin	2545	16600	15600	−1000	.....
Copper	2600	17000	16000	−1000	.....
Gold	2885	18600	18200	−400	.....
Platinum	4270	25800	29900	4100	.....
Tungsten	5280	44000	39600	−4400	.....
Water	373.0	2160	1820	340	9650
Ethyl alcohol	351.4	2170	1600	570	9500
Phenol	454.4	2520	2240	280	10680
Acetic acid	392.2	2200	1920	380	5650
Aniline	456.9	2510	2250	260	10500
Acetophenone	474.5	2550	2360	190	10700

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LE I.

(7) Lcalc	(8) Lcalc / Lobs.	(9) 4.23 x Scale	(10) Trouton	(11) Binghan	(12) Nernst	(13) Sobs / Tb	(14) (13) + 2.881
26.5	.....	.....	92.5	73.3	25.8	1.350	4.231
228	0.92	190	435	350	250	2.475	5.356
1435	1.062	1333	1660	1380	1345	4.060	6.941
1740	1.068	1610	1940	1620	1630	4.214	7.095
2010	.....	1960	2340	2150	2020	4.046	6.927
3660	.....	3675	4025	3575	3810	4.260	7.141
4110	1.065	3680	4080	3630	3850	4.732	7.613
4200	1.065	4020	4400	3950	4210	4.487	7.368
4570	1.015	4145	4540	4090	4370	4.720	7.601
5260	1.213	4660	5030	4580	4885	4.915	7.796
4940	1.062	4785	5150	4720	5020	4.500	7.381
5990	1.040	5780	6140	5750	6090	4.590	7.471
6035	1.040	5925	6250	5870	6240	4.530	7.411
6400	1.090	6140	6460	6120	6450	4.650	7.531
6630	1.025	6265	6620	6280	6600	4.702	7.583
6720	1.087	6310	6630	6300	6650	4.755	7.636
6630	1.050	6520	6850	6550	6880	4.545	7.426
7225	1.138	6735	7080	6810	7130	4.792	7.673
7225	.....	6775	7100	6820	7145	4.780	7.661
7360	1.057	6840	7115	6840	7180	4.857	7.738
7410	.....	6860	7155	6890	7230	4.860	7.741
7600	1.111	7030	7340	7090	7410	4.860	7.741
7730	1.092	7140	7445	7210	7520	4.877	7.758
7600	1.067	7240	7540	7320	7640	4.727	7.608
7860	1.070	7285	7590	7390	7670	4.865	7.746
7860	.....	7285	7600	7395	7680	4.860	7.741
8000	1.052	7410	7690	7500	7800	4.888	7.769
8230	1.085	7685	7970	7830	8090	4.850	7.731
8650	1.082	7915	8200	8150	8380	4.944	7.825
8600	1.082	7940	8230	8170	8400	4.900	7.781
8650	1.094	8000	8315	8240	8490	4.880	7.761
9010	1.111	8280	8560	8510	8740	4.940	7.821
9055	1.084	8380	8700	8690	8890	4.890	7.771
9380	.....	8640	8895	8920	9090	4.954	7.835
9700	1.102	8980	9205	9310	9450	4.950	7.831
10020	.....	9150	9400	9550	9650	5.004	7.885
10610	.....	9470	9700	9910	9960	5.140	8.021
10300	1.092	9655	9910	10200	10190	4.874	7.755
10520	1.164	9750	9960	10220	10280	4.910	7.791
10890	.....	9895	10110	10420	10600	5.059	7.940
11160	1.111	10240	10440	10820	10740	5.027	7.908
11250	1.097	10380	10580	11000	10880	5.000	7.881
12220	1.011	11320	11450	12190	11870	5.020	7.901
12710	.....	11720	11850	12700	12200	5.045	7.926
12810	.....	11820	11900	12800	12300	5.059	7.940
12920	.....	11860	11980	12880	12380	5.074	7.955
13400	.....	12200	12290	13300	12630	5.130	8.011
14130	.....	13120	13140	14500	13550	5.055	7.936
14280	.....	13240	13220	14600	13650	5.070	7.951
14500	.....	13420	13410	14900	13880	5.080	7.961
14050	1.030	13550	13550	15100	14000	4.874	7.755
16920	.....	15670	15500	17950	15900	5.140	8.021
26300	1.118	23920	22720	30200	22550	5.435	8.316
31500	1.235	27500	25780	36200	24900	5.746	8.627
41150	.....	38200	34420	55350	30800	5.622	8.503
46170	.....	43150	38300	65100	32750	5.674	8.555
48300	.....	44650	39400	67950	33300	5.573	8.454
60100	.....	55900	47650	91900	40600	5.930	8.811
75950	.....	66000	54800	114600	36600	6.518	9.399
77700	.....	67700	56000	118800	36900	6.540	9.421
85000	.....	77000	62100	140800	36500	6.448	9.329
118200	.....	126700	91900	273200	19500	6.050	8.931
201200	.....	167800	94600	344000	−8560	8.320	11.201
9880	1.022	.....	.....	.....	.....	.....	.....
9920	1.044	.....	.....	.....	.....	.....	.....
11510	1.078	.....	.....	.....	.....	.....	.....
10050	1.778	.....	.....	.....	.....	.....	.....
11470	1.091	.....	.....	.....	.....	.....	.....
11650	1.090	.....	.....	.....	.....	.....	.....

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the log P vs 1/T curves for normal liquids with a degree of precision approaching that often found in the recorded experimental results.

In column 6, Table 1, are given the molecular latent heats of vaporization of some of these liquids. These results have been calorimetrically determined. Column 7 shows the values of the latent heats calculated as shown in equation (2). These values have been obtained by multiplying the observed slope (column 3) by 4.58. Column 8 shows the ratio of the calculated to the observed latent heats. It will be observed that in all cases below hydrogen the calculated result is larger than the observed. This difference averages about 8%. This, then, is equivalent to changing the constant 4.58 to 4.23. Accordingly, a new empirical equation for calculating latent heats of vaporization may be developed by combining equations (2) and (3) and using the constant 4.23 instead of 4.58, viz.,

$$L_v = 4.23\,(-68 + 4.877\,T_b + .0005\,T_b^2) \quad \ldots\ldots\ldots\ldots (4)$$

In columns 9, 10, 11 and 12, Table I, are given, first, the latent heats of vaporization calculated from equation (4), second, from Trouton's[3] equation, $L_v = 21.5 \,.\, T_b$:— .....(5) third, from Bingham's[4] equation, $L_v = (17 + .011\,T_b)\,T_b$, ...(6) and fourth, from Nernst's[5] equation, $L_v = (9.5 \,.\, \log T_b - .007\,T_b)\,T_b$.....(7)

Comparing the results obtained by these various equations with those obtained by direct measurement, it will be observed that at the very lowest temperatures, Nernst's equation gives the best results. At all other temperatures, except for isolated cases, equation (4) gives as good, if not better, results than any of the others. At high temperatures it is very evident that equation (4) gives much the best results. Nernst's equation actually goes through a maximum and finally to negative results. The results obtained by Trouton's rule are also much too low at high temperatures, while those from Bingham's equation are much too high.

Finally, Table I contains the values for the constant, C, in equation (1). In column 13 are given the values of the constant which should be used when the pressure is

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to be calculated in atmospheres. This constant is found by dividing the observed slope of the log P vs 1/T curves by the absolute boiling point. By adding the value of the logarithm of 760, which is practically 2,881, to the numbers given in column 13 there is obtained the value of the constant to be used in order to represent the vapor pressure in mm. of mercury. These values are given in column 14. This constant increases as the boiling point of the substance in question increases.

In order to show the limitations of this method of calculating vapor pressures and heats of evaporation, there are collected at the bottom of Table I the data for some typical associated liquids. In general it may be said that the simpler compounds containing hydroxyl, amino, carbonyl and carboxyl groups and most molten salts will deviate more or less from the general rule for normal liquids. For these classes of liquids there will be needed at least two values of the vapor pressure or one value of the vapor pressure and the latent heat of evaporation in order to write the vapor pressure equation. It should be noted also that the vapor pressures of the more strongly associated substances may not be accurately represented by the straight line equation except through relatively narrow ranges of temperature.

Having given a simple expression for the vapor pressure of liquids, the question may be asked, Can a similar expression be derived for the sublimation pressure of solids? Happily the answer is that a similar expression exists, and that for many substances the constants may be empirically calculated from existing data.

It has been shown that in the expression,

$$\text{Log } P = C - S/T \qquad (8)$$

the constants C and S may be calculated for normal liquids from the boiling point alone. In any case they may be calculated from two simultaneous values for log P and T. Now it may be shown that there is an exactly similar expression for sublimation pressure, viz.,

$$\text{Log } P_s = C_s - S_s/T \qquad (9)$$

in which P_s is the sublimation pressure at the tempera-

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ture T, and C_s and S_s are constants having the same significance as in equation (8).

The constant S_s is related to the heat of sublimation by the expression,

$$S_s = L_s / 4.58 \quad (10)$$

Now the latent heat of sublimation is equal to the sum of the heats of fusion and of vaporization, or,

$$L_s = L_f + L_v \quad (11)$$

Equation (4) furnishes a method for calculating L_v, leaving then only the latent heat of fusion to be obtained. A careful search has revealed the fact that there are relatively very few reliable measurements of the latent heat of fusion recorded in the literature, and almost no data are available for substances melting below 0°. Several empirical rules for calculating the latent heat of fusion have been proposed. Probably the simplest and most generally useful is that proposed by Walden[6], by which the molecular latent heat of fusion is equal to the absolute melting point times a constant, or,

$$L_f = T_m K \quad (12)$$

Walden has shown that the constant K has a value equal to about 13.5 for many organic compounds. This value is, however, too high for many classes of substances After considering all of the available data upon the latent heats of fusion, we have concluded that the following tentative values for Walden's constant may be used for calculating the latent heats of fusion of these classes of substances here represented.

Substance.	No. of substances investigated.	Mean value of L_f/T_m=K.	Av. deviation from mean.
Metals	18	2.6	0.3
Aromatic Hydrocarbons	10	12.8	0.5
Halogen Compounds	15	13.5	0.5
Nitro Compounds	6	13.5	0.1
Nitro Halides	6	13.5	0.5
Amino Compounds	7	11.0	1.4
Aromatic Hydroxy Substances	5	6.9	0.3
Aromatic Acids, Anhydrides and Ketones	7	12.1	1.0

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There is insufficient data to indicate what would be the value of this constant for mixed derivitives, but in general, it may be said that the higher the molecular weight and the higher the melting point, the larger will the constant tend to become in any of the series of compounds investigated.

Assuming, then, that L_s, the latent heat of sublimation, is known or may be calculated from equations (11) and (12) there still remains the constant C_s to be determined. This is accomplished readily when it is remembered that, at the melting point, the vapor pressure is equal to the sublimation pressure. Hence,

$$C_s - S_s/T_m = C - S/T_m \quad \ldots\ldots (13)$$

from which C_s may be calculated.

It should be remembered that there is an independent method of calculating the latent heat of fusion of solids from their solubilities and freezing point lowering. In order for this method to yield accurate results, however, the substance chosen as solvent must be one which will form a thermodynamically ideal mixture, or, otherwise there must be introduced a factor which will correct for the non-ideality of the given mixture. In a recent paper the Author[7] has described a method for determining this factor, and hence for finding the latent heat of fusion, for several classes of organic substances. It is probable that the principles there discussed would apply to other classes of compounds as well, but at present there is too little data to enable one to make a comparison.

In conclusion, it may be said that, from the principles outlined above, it should be possible to determine the vapor pressures, the sublimation pressures and the heats of vaporization, of sublimation and of fusion for normal substances when only the freezing point and normal boiling points are known.

SUMMARY

Empirical methods for evaluating the constants in the vapor pressure and sublimation pressure equations, $\log P = C_v - S_v / T$ and $\log P = C_s - S_s / T$ have been given and their significance discussed.

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An empirical method for calculating the latent heat of vaporization of normal liquids has been given which gives very good results for liquids boiling from about 20° Abs. up to those boiling at the highest temperature so far investigated.

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Contribution from the Chemical Laboratory, Illinois Wesleyan University.

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SOUNDPROOFING IN BUILDINGS

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The demand for quiet rooms in hospitals, hotels, and office buildings, the desirability of insulating music studios and other rooms where disturbing sounds are produced, have led to repeated requests from architects and builders for reliable information on effective methods for insulating sound. Although present knowledge of the subject is incomplete, nevertheless, on account of the pressing need for guidance in such matters, it is thought desirable to collect and present the available information in a systematic way, giving the methods and results of various investigations relating to the action of materials on sound, describing practical installations of soundproofing, and setting forth in accordance with existing knowledge recommendations that may be applied where sound insulation is wanted.

This introductory statement in a recent bulletin* on "Soundproof Partitions" indicates the lack of information on the subject of soundproofing.

The action of sound in a building is much of a mystery to many people. There is a popular belief that wires stretched in an auditorium will be of benefit for faulty acoustics, or, if this fails, that a sounding board over the speaker's head will remedy matters. Also, concerning sound proofing in buildings, an impression prevails that an effective wall is one containing air spaces. These popular conceptions are not altogether supported by the facts. People who regard the problems with a degree of seriousness realize that the action of sound is not a matter of chance, but that the phenomena must accord with scientific laws.

In the bulletin mentioned, the results are given of a survey of the subject of sound insulation in buildings from three standpoints,—the theory of the subject, experimental investigations, and practical installations of soundproofing. This information thus collected, while

* "Sound-Proof Partitions" Bulletin 127, University of Illinois Engineering Experiment Station.

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drawn from different sources and apparently unrelated, proved quite concordant and led to conclusions concerning effective sound insulation.

Two Types of Sound in Buildings.—Two types of sound should be considered in the problem of insulation in buildings. One type includes sounds that are generated in the air and that progress through the air to the boundaries of the room; the other is composed of compressions generated in the building structure by motors, elevators, and street traffic.

Insulation of Sounds in Air.—Sounds of moderate intensity such as those generated by the human voice or a violin may be stopped with comparative ease if the walls of the room are continuous and fairly rigid. The more vigorous sounds of a cornet, trombone, etc., would require especially heavy walls or else double partitions. Any breaks in the walls for ventilators, pipes, or doors should be guarded by effective insulation.

Insulation of Building Vibrations.—Compressional waves generated in the building structure pass readily along the continuity of solid materials, and, as they have more paths for escape, are more difficult to insulate than sounds in air. Moreover, they may create trouble when they cause a wall or floor to vibrate. The insulation is based on the same procedure as that used for air sounds; namely, to interpose a new medium differing in elasticity and density. An air space in masonry would be effective if not bridged over by solid material, but since this is impossible for ordinary building constructions as the weight of bodies necessitates contact for support, an approximate insulation is sought by using air-filled substances like dry sand, ground cork, hairfelt, or flax, that possess but little rigidity but are capable of sustaining a floor or a partition that is not too heavy.

Transmission of Sound.—Sound waves in air may be transmitted through an obstructing medium in three ways. First, they may pass through the air spaces of a porous material. Second, they may be transmitted by modified waves in the new medium. In this process sound compressions and rarefactions progress rapidly

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through the air, moving the molecules successively as they pass in somewhat the same way as a gust of wind blows the separate stalks in a wheat field. On reaching a solid partition the forward motion is hindered, particularly if the molecules of the new material are massive and resist compression. In this case most of the energy is reflected and only a small proportion progresses through the wall. On meeting a further discontinuity of material, such as wood or air, the waves are again affected, until finally a part of the energy emerges. Third, sound may be transmitted by setting a partition as a whole in vibration. The partition then acts as an independent source of waves, setting up compressions and rarefactions on the farther side and giving a sort of fictitious transmission. If the partition is rigid and massive the vibrations are small and very little sound is transmitted; if the partition is thin and flexible a considerable amount of energy is transferred.* Usually in building constructions the partitions are complex, as for example plaster on wood lath and studding. In this case the plaster areas between the studding act in a manner similar to drum heads and transmit sound. Hard plaster on wire lath presents a different surface with a modified action on the incident sound.

The transmission of sound involves a number of phenomena and is not a simple matter. It depends essentially on the character of the structure through which sound is transmitted and can be calculated only for simple cases of homogenous materials of known constants.

The systematic survey of the subject of soundproofing as given in the Bulletin leads to several practical conclusions.

Ventilation System.—Especial attention should be paid to the ventilation system. All effective soundproof constructions either omit entirely a ventilation system or else construct it in some special manner to avoid transmission of sound. In some buildings air is sup-

* Rayleigh, Lord. "Theory of Sound", Vol. 2, Sections 270-272, see also:
Jager, G. "Zue Theories des Nachhalls", Sitzungber. der Kaisl. Akad. der Wissenschaften in Wien. Math. Natur. Klasse, Bd. CXX, Abt. 2a, 1911.

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plied and withdrawn from rooms by individual pipes that are small in diameter and extend without break from the air supply chamber to the rooms. This results in considerable friction between the walls of the pipes and the air, with a resultant weakening of the sound waves. Without some efficient control of the transference of sound through the ventilation system, it is a waste of effort to construct soundproof walls, double doors, and other contrivances for insulation.

Soundproof Partitions.—Partitions between rooms should be as rigid and free from air passages as possible. For effective soundproofing of a group of rooms, the partitions, floors, and ceilings between adjacent rooms should be made continuous and rigid. Any necessary openings for pipes, ventilators, doors, and windows should be placed in outside or corridor walls where a leakage of sound will be less objectionable.

Absorption of Sound.—The absorption of sound is an essential feature for soundproofing. Reflecting sound and scattering it still leaves it with energy. It must be absorbed; that is, converted into heat energy by friction, before it is eliminated as sound. This means that carpets, furniture, draperies, etc., should be present, or if greater absorption is desired, hairfelt or similar materials must be installed.

Soundproofing a Building.—*When soundproofing a building, all details should be considered with respect to the likelihood of transmission of sound. Each room, as far as possible, should be made an insulated unit by means of air spaces or air-filled materials that separate it from surrounding walls. Pipes and ventilators should be so installed as to minimize the chance of transfer of sound. Patent doors are now available that will close the door space at top, sides and bottom. In case a troublesome sound is generated in the room, it may be minimized by installing absorbing material on the walls.

The insulation of sound is a complex problem, and a successful solution is obtained only when all the possibilities of transfer of sound are anticipated and guarded

* "Soundproofing a Building", Architectural Forum, November, 1921.

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against. While many things may be learned from further experience and much may be gained from additional theory, enough has been revealed to give encouragement to the belief that soundproofing may be prescribed in the future with some of the certainty that now attends the acoustic design of auditoriums.

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A SIMPLE DEVICE FOR THE ANALYSIS OF SOUND WAVES

C. J. Lapp, University of Illinois

This sensitive device was designed while research was being done on the wave form of the sound emitted by C. T. Knipp's singing tube. The principle used is similar to the one employed by D. C. Miller in his phonodeik. The optical reflecting system, however, was entirely different, being at the same time much simpler. The diaphragm of dermatype paper was stretched over a two inch circular opening in a brass plate, 0.159 cm. in thickness, and held in place by a flat brass ring of the same thickness screwed to the plate. To the center of the diaphragm were attached perpendicularly four or five silk fibers, the other end of which was held by a very fine conical aperiodic spring. Across the diaphragm, 0.476 cm. above and parallel to it, was very tightly stretched one strand of a three strand silk thread. This was passed 0.154 cm. from the perpendicular fibers. A small mirror, 0.0435 cm. in width and 0.154 cm. long, was mounted with its plane parallel to the diaphragm between the horizontal silk strand and the vertical silk fibers. When a sound wave was caught by the diaphragm the mirror vibrated with it around the horizontal silk strand, causing a beam of light to vibrate and trace out the sound wave form on a moving photographic plate.

F. A. Schultze* has shown that paper is aperiodic and that a paper diaphragm is sensitive to sounds of any wave length. The dermatype paper used was taken from dermatype stencils manufactured for the Edison-Dick mimeograph. This paper is flexible, and very strong.

In the diaphragm mounting the author has incorporated some new features which are shown in Figs. 1 and 2. No horn or resonating device of any sort was used in any of the work to increase the intensity of the sound brought to the diaphragm. Professor Foley, of Indiana University, read a paper before the St. Louis meet-

* Annalden d. Physik IV, Folge, Vol. 24, p. 75, 1907.

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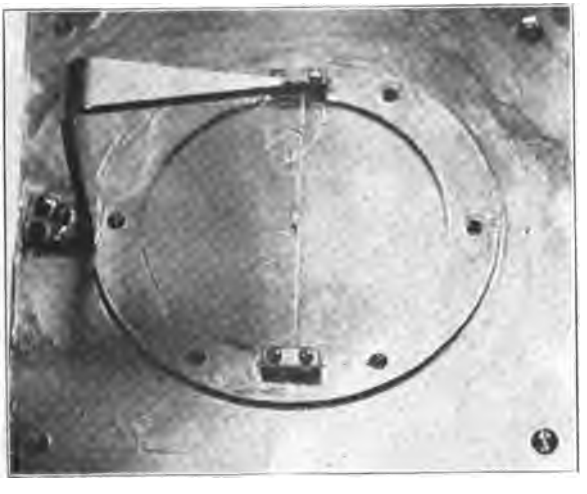

Figure 1.

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ing of the American Physical Society in December, 1919, in which he clearly demonstrated the distorting effects of bent tubes and straight horns on sound waves. Although this diaphragm mounting was designed before Professor Foley's paper was read, the author was very careful in the designing to avoid air pockets of any sort.

The inertia of the moving parts of the mounting is probably smaller than that of any diaphragm mounting heretofore used in sound-wave analysis. The only masses involved are, the mass of three or four silk fibers 3 cm. long, the mass of the mirror 0.154 cm. long, 0.0435 cm. wide and of microscopic thickness, and the mass of the small specks of shellac used to mount the mirror.

The spring used was made by winding No. 40 steel wire on a brass cone of small dimensions. The period of any

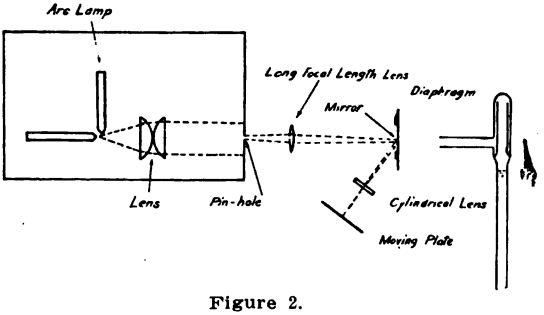

Figure 2.

spring is a function of its diameter and the elasticity of the material used. The diameter of each turn of wire was different from that of any other; therefore each turn had a different period and the spring as a whole was aperiodic. While in use a small tuft of cotton was placed inside the spring to damp out sidewise vibrations.

The other details of the set-up may be seen easily from the diagram, Fig. 2. This device was found to be very sensitive as is demonstrated by the photographs taken with it in Fig. 3. This is a series of curves taken to show that the diaphragm as used was sensitive to even the faintest overtones. Wave A is the sound wave of an open organ pipe. Several overtones can be found in the wave. Wave B represents the sound wave produced by two tubes sounding together, no resonator being used

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on either tube. This wave demonstrates the ease with which the dermatype diaphragm followed a complex wave form. At least six wave forms can be traced in this curve.

Waves C, D, and E were taken by C. T. Knipp during the author's absence. In C, the two L-form tubes used were adjusted to each, giving its maximum tone with a resonator attached. A slight adjustment of either gave any desired beat frequency. This curve is exceedingly clear cut and bears a critical study under a glass. For each tube the energy was being supplied by one burner; hence the components of the wave should be nearly pure sine waves. Ununiform motion of the film makes the beats appear to be of different sizes. In D the same two tubes were adjusted to nearly unison, giving six or seven beats per second. The other conditions were the same as in C. In E there was superimposed upon D the tone emitted by a high pitch organ pipe blown to sound its fundamental. The film was moving some faster, otherwise the conditions were the same. Wave F was taken from three open organ pipes sounding together. The pipes ranged from a very low to a very high pitch, and were being blown with considerable pressure so as to produce overtones in each one. This is not a hap-hazard curve as it appears at first sight, but rather an ordered succession of a single configuration, three of which appear on the photograph. Wave G represents a note from a French horn. The wave forms represented in B, E, F and G should remove from the minds of even the most skeptical any doubt as to the sensitivity of the diaphragm.

The author wishes to express his thanks to Professor C. T. Knipp for his encouragement and assistance in this work, and to Professor A. P. Carman for the facilities of the department.

Laboratory of Physics
University of Illinois
January, 1922

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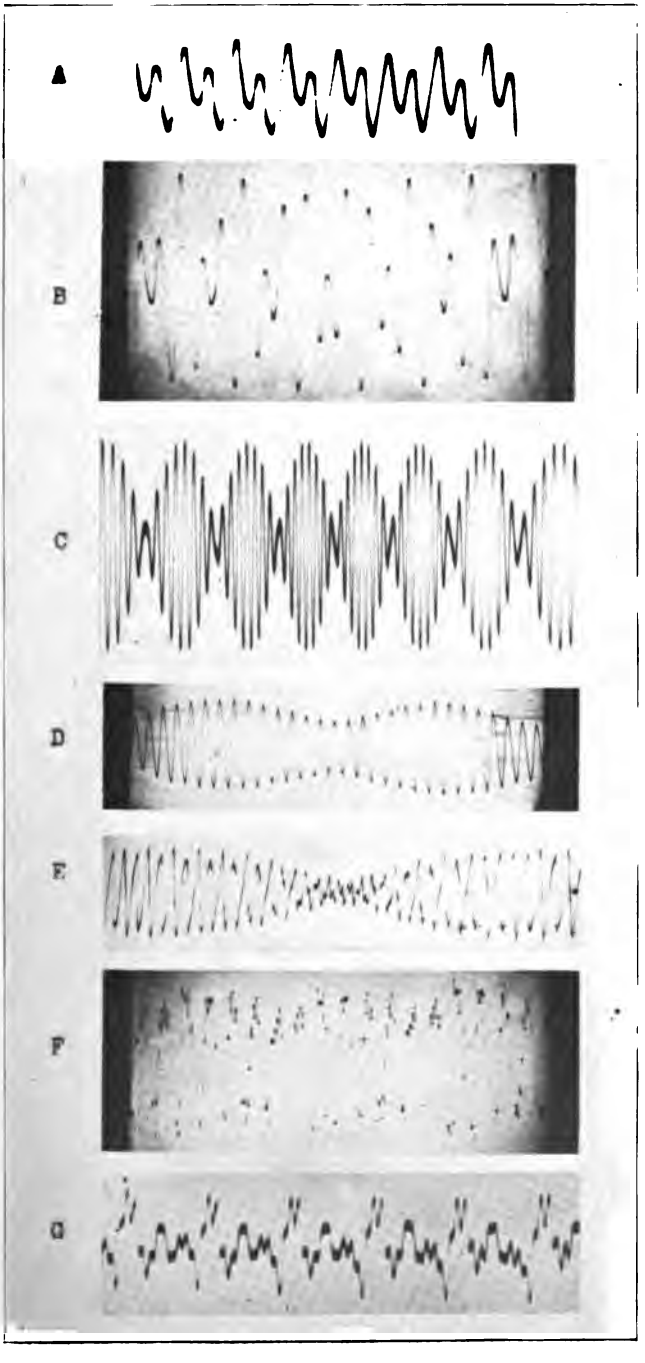

Figure 3.

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A 3000-VOLT LEAD PLATE SHOP-MADE STORAGE BATTERY—ITS CONSTRUCTION AND CHARGING CHARACTERISTICS

C. T. Knipp and R. J. Ruedy, University of Illinois

In the modern well equipped physics laboratory, whether in secondary school or university, sources of direct high electromotive forces are becoming increasingly more important. It is not the object of this paper to enumerate the uses of such potentials, but rather to describe in some detail a battery of 3000 volts that was built during the past winter by one of the writers and which is now in commission and is giving excellent service. This battery is a shop-made one, meaning thereby that the complete installation, i. e., the lead plates, multiple switches for charging and discharging, binding posts, and the cupboard in which the cells are assembled, was made in our physics shop. The 1500 test tubes necessary were especially blown by the Central Scientific Company, Chicago.

The cells are grouped in trays of 20 each, and thus each tray has a potential, when fully charged, of 40 volts. The trays are constructed of wood, and in appearance are similar to a test tube rack as may be seen in Fig. 1. Each tray was boiled in paraffine for 15 to 20 minutes. After cooling it was dipped again in paraffine so as to thoroughly protect the wood from the acid, and also to improve the insulation.

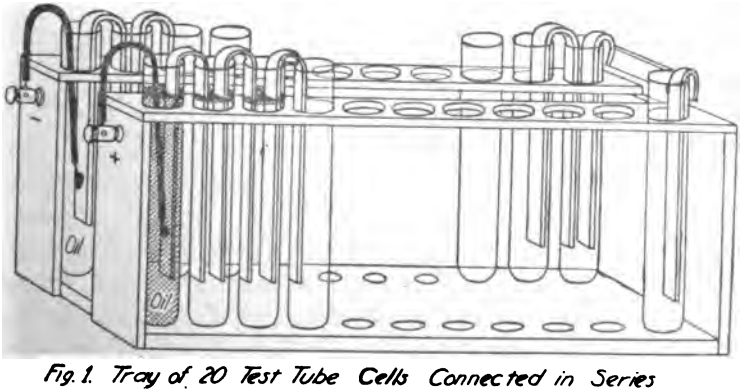

Fig. 1. Tray of 20 Test Tube Cells Connected in Series

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Each individual cell consists of a glass test tube, 1 to 1¼ inches in diameter, and 5 to 6 inches long, in which are placed two strips of sheet lead and a quantity of dilute sulphuric acid. To protect the electrolyte from evaporation it is covered with a thin layer of oil which also tends to prevent the acid from being thrown off in spray while charging the battery. A general idea of the wooden tray and assembled cells may be obtained from Fig. 1. The purpose of the two auxiliary tubes, next to the binding posts and filled with oil, is to prevent the acid from creeping. The oil also protects the soldered joints.

The plates were made of sheet lead 1/8 inch thick. After cutting it into strips of the desired width, they were run through two corrugated rollers, giving them somewhat more surface, and also providing recesses to hold the active material formed in charging. These strips were then cut into the desired length, each length providing two plates when bent into shape. The strip thus bent was placed astride two cells, one plate forming the positive electrode and the other the negative of the adjacent cell. The lead plates being heavy, but little warping will result; hence no separators are necessary.

The manner of putting the cells together is clearly shown in the figure. The time required for the formation of the lead plates may be considerably shortened by treating them before assembling in strong nitric acid for from four to six hours. The plates were then rinsed in water and placed in position. Dilute sulphuric acid of density 1.25 to 1.30 was used as the electrolyte, and a protecting film of oil was placed over it. The cells thus assembled were allowed to stand for several days before beginning to charge them. During this interval a coat of lead peroxide formed on the plates.

In the formation of the plates, a small current (about 1/10 of an ampere) was sent through each cell. Larger currents caused excessive bubbling, which is objectionable since it tends to prevent the formation of active material on the plates. The charging was allowed to continue until they were all gassing freely, which required about 8 hours.

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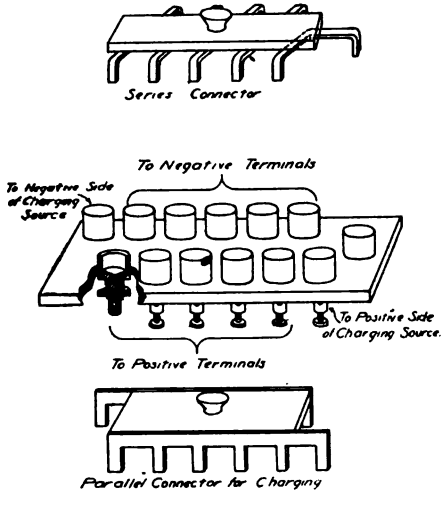
The charging source was then disconnected, and the cells discharged through a resistance at a rate about equal to that of charging. After they were discharged the cells were allowed to stand for a day and then charged as before, but now in the opposite direction, forming lead peroxide on the plate which had previously been negative. When the cells were again gassing freely the same procedure as before was followed in discharging them. The above cycle was then repeated until they seemed to have reached their maximum capacity. About 15 such cycles



MULTIPLE SWITCH

Figure 2.

were required, after which they were charged and discharged a few times *without reversing the polarity,* and after a final charge were put into use.

In charging the cells the trays containing them were always placed in parallel; thus the charging voltage necessary was but little in excess of that of each tray. Since there are twenty cells in each tray the charging voltage need not exceed 45 volts. However, to obtain a high voltage on discharge when using them the trays must be connected in series. Thus five trays when fully charged give when connected in series 200 volts.

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To facilitate the changing of connections a multiple switch was constructed (Fig. 2) which accommodates 5 trays, the number assembled on each shelf of the cupboard. The terminals of each tray are brought to a pair of mercury cups, as indicated in Fig. 2. The positive terminals are connected to the front row of cups, and the negative to the back row. The leads from the charging source are connected to the two end cups as shown. Two types of connectors are used which consist of copper or brass legs attached to a block of hard rubber. The legs are arranged to set in mercury cups. The one type has all of the legs on the front side connected together, and likewise on the back so that when it is inserted the trays are all connected in parallel,—positive all together on the front and negative on the back. The other type has the legs connected across diagonally so that when the connector is in place the positive terminal of one tray is connected to the negative terminal of the next and so on. One multiple switch is provided for each shelf of five trays. In order to connect the different shelves together in series diagonal cross wires are used. These wires show in Fig. 3.

The particular installation which is the subject of this paper, consists of 1500 cells, or 75 individual trays assembled in three tiers of 25 trays each. The total potential when all are in series and fully charged is 3000 volts. In order to reduce any leakage to a minimum value, the five trays on each shelf are supported on an individual paraffined shelf which in turn is supported by four porcelain insulators. In this way each 200 volts is thoroughly insulated from the cabinet as a whole. An idea of this method of assembling may be obtained from Fig. 3.

In building such a battery, it is, of course, not essential that the cells be grouped as described. Almost any number of individual cells may be incorporated in one tray, but it seems that for maximum convenience twenty cells to a tray is about the right number, for if more are added the tray becomes large and heavy.

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Figure 3.

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The current capacity of such a battery is naturally very low. It should be used primarily for potentials only, or for very small currents of the order of a few milliamperes. The cells will, however, deliver about 1/10 ampere, but for a short time only, the voltage soon dropping off. Cells constructed of sheet lead and formed as these should be charged regularly once per week whether they are used or not. For convenient charging the trays should be mounted in a cupboard as described, where the individual trays may be returned for charging. If preferred the cupboard may be replaced by three cabinets of 1000 volts each mounted on rubber tired castors, thus making the battery available in different rooms.

University of Illinois
Laboratory of Physics
April, 1922

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DEMONSTRATION OF THE WIND IN THE CORONA DISCHARGE

JAKOB KUNZ, UNIVERSITY OF ILLINOIS

The characteristic pressure increase observed in the corona discharge can be explained by the assumption that the positive ions arising from the luminous layer surrounding the positive wire transmit their momentum to the gas molecules, according to the principle: ne E dt=dp2nr.* It was found that the mobility of the positive ions in various gases is remarkably low, and therefore the pressure increase rather high, amounting in several experiments to 2 and 3 cm. of water. If the corona discharge takes place in an open gas between parallel wires, then we observe the mechanical momentum as a wind away from the positive wire, whereas in a closed cylinder the wind makes itself felt as pressure increase.

The experimental arrangement was very simple. Two wires of 0.12 mm. diameter, 30 cm. long, and 3 cm. apart, were stretched between two hard rubber plates and a potential difference was applied from 0 volts up to 18000 volts from a battery of dynamo machines. In a wash bottle was put a small quantity of ether, so that no bubbles were formed by the slow stream of air which was driven through the bottle, carrying ether vapors with it. This stream of air and ether vapor passed through a stop cock, a glass sphere of 10 cm. diameter, and escaped through a capillary of about 1 mm. opening into the air between the parallel wires, forming a beautiful regular jet of arbitrary length. This jet between the wires was projected by means of an arc without lenses on a screen. The distance between the arc and the wires was about 1.5 m., and this was also the distance between the wires and the screen.

When a potential difference of 15000 volts was applied no deflection of the jet could be observed; there was, however, a small deflection for a potential difference a

* On the Pressure in the Corona Discharge. Phys. Rev., Vol. 19, p. 165. 1922.

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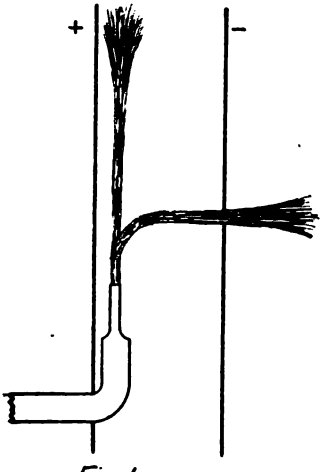

Fig. 1

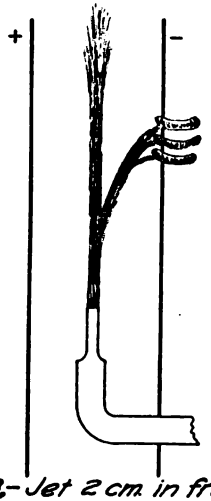

Fig. 3,—Jet 2 cm. in front of plane of wires.

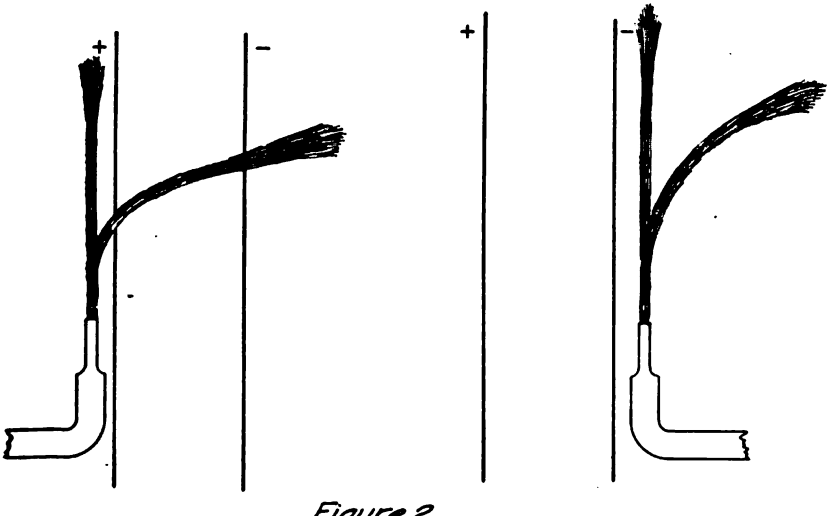

Figure 2

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little below the critical difference for which the positive corona became visible. As soon as the corona appeared in the form of a uniform layer of weak light surrounding the positive wire, then the deflection of the jet of ether was very marked, as indicated in the following photographic picture and in the drawings made on the screen directly. The deflection could be varied at will by changing the air current through the ether, or the potential difference across the wires. The two variables could easily be adjusted so that the originally vertical jet was directed at right angles and passed a long distance beyond the negative wire. The largest deflections were obtained when the capillary was set between the two wires about 5 mm. away from the positive wire. See Fig. 1. But even when the capillary was placed behind the negative wire or in front of the positive wire, a marked deflection was obtained, as can be seen from Fig. 2. Finally, if the capillary was placed about 2 cm. outside the vertical plane containing the wires, a considerable deflection was observed as indicated by Fig. 3. These 3 figures indicate the strong wind blowing from the positive to the negative wire.

Instead of ether a jet of ammonium chloride or of water vapor can also be used. The water vapor jet appeared darker with the corona discharge than without it, indicating the condensation of water vapor around the ions. In the photographic picture the corona took place between a positive wire of 0.3 mm. diameter and a negative wire of 1.25 mm. diameter. It was observed that when the potential difference was applied in the first instant the positive wire was surrounded by diffused streamers of light, which disappeared suddenly, giving rise to the uniform positive layer of light. This observation may help to explain the beginning of the corona.

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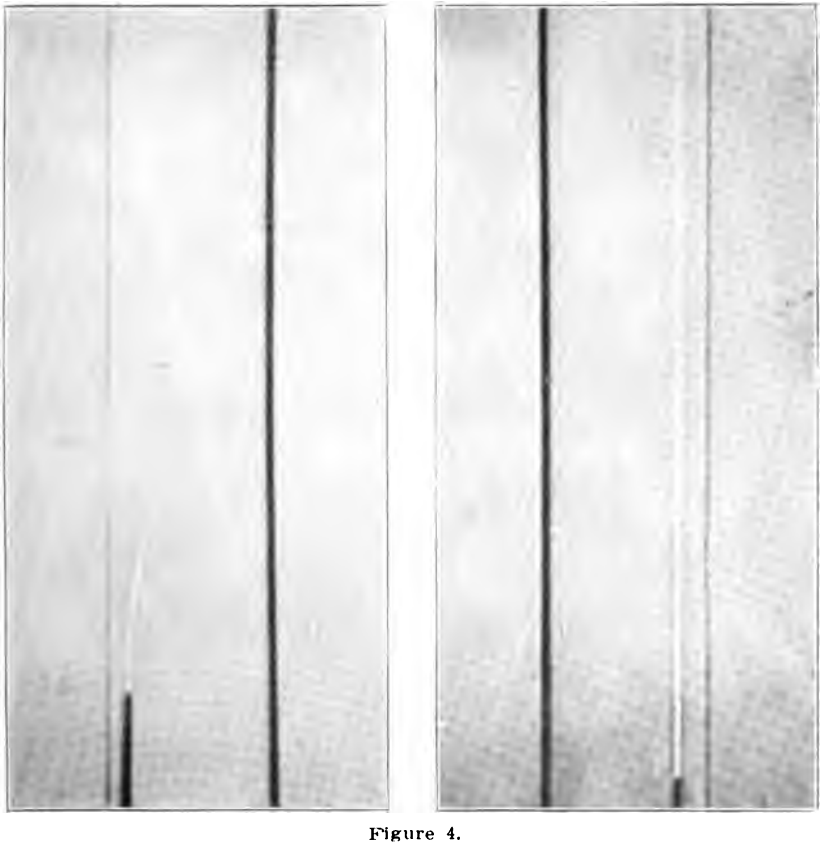

Figure 4.

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THE ADSORPTION OF HYDROGEN IONS BY CHARCOAL

(Abstract from original paper.)

I. J. JENKS, STATE TEACHERS COLLEGE, DEKALB

INTRODUCTION

It is a well established principle of colloid chemistry that the ions of an electrolyte are adsorbed by certain precipitates and the similarity of this adsorption of gases by charcoal has been pointed out.

W. Mansfield Clark in "The Determination of the Hydrogen Ion" (Page 34) mentions the work of Bovie as showing the adsorption of both hydrogen and hydroxyl ions by charcoal, when present during an electrometric titration. Bovie (J. Med. Research 295-317-1915) found that the presence of .5g of Kahlbaum's animal charcoal in a 0.01-N solution of alkali strongly depressed the hydroxyl ions concentration and prevented also the appearance of hydrogen when the solution is titrated with .01-N HCl, the usual symmetrical curve being markedly flattened out on both sides, with the vertical rise which marks the end point entirely obliterated.

Bovie points out the similarity of the effect to that obtained in a true "buffer" solution, but attributes the buffer effect to adsorption of both hydrogen and hydroxyl ions by the charcoal.

Two objections to this interpretation of Bovie's experimental curve may be noted. In the first place it is not common to find both hydrogen and hydroxyl ions equally adsorbed; usually adsorption of hydrogen ions is much more marked. In the second place, Bovie did not take into account the possibility of salts contained within the charcoal, in spite of the fact that animal or bone charcoal almost certainly contains calcium phosphates which are among the most effective buffers. (See A. H. Clark, Masters Thesis, U. of C. 1920, Pages 19-23, 58-65.)

This research was therefore undertaken to investigate this factor and to determine whether pure charcoal shows

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a similar buffer action. The results show that the apparent buffer effect produced by animal charcoal is probably caused by chemical action of the alkali or acid added upon the adsorbed gases and salts contained as impurities in the charcoal, rather than by any true adsorption by the charcoal itself. Obviously most animal charcoal contains small quantities of impurities such as phosphates, carbonates, tartrates and oxalates together with some salts of calcium, sodium, or potassium and also adsorbed gases such as carbon dioxide and hydrogen sulfide.

To test their effects, titrations were made with the various grades of commercial charcoal obtainable, and with charcoal made from pure cane sugar and containing no mineral salts. The results obtained in these titrations are plotted as curves on which the conclusions are based.

The titrations were made with a simple titration apparatus devised in the laboratory and similar to one described in Central Scientific Co. Bulletin No. 86. This method of titrations is especially suited for the purpose, because it indicates the actual hydrogen ion concentration at all times and also gives the neutralization point. Furthermore, the charcoal suspensions are so black that indicator changes could not be clearly marked.

EXPERIMENTS

The first experiment was made with a sample of commercial animal charcoal bought on the market, the titration being made with N/20 sodium hydroxide and N/20 HCl. Curve I, Plate I, represents the normal curve for this alkali and acid.

A second titration was then made by first running in 25cc. of the alkali, then adding one gram of the charcoal. No change was observed in the voltage or Ph. reading upon the addition of the charcoal, but as the titration was carried out the curve (curve II) follows the normal until near the neutral point; then instead of showing an abrupt drop it is straightened out, indicating the elimination of the hydrogen ions of the acid by adsorption or by the action of some substance which interacts with the

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acid. Even the addition of a large excess of the acid brings the Ph. value down to slightly below the neutral point.

The experiment was then repeated, using oxalic acid instead of the hydrochloric, with practically the same results.

These curves are quite different from that of Bovie, as his curve is affected on both sides of the neutral point. That is, his curve is lowered much below the normal curve before reaching the neutral point, while the curve for this charcoal is only affected on the acid side of the line.

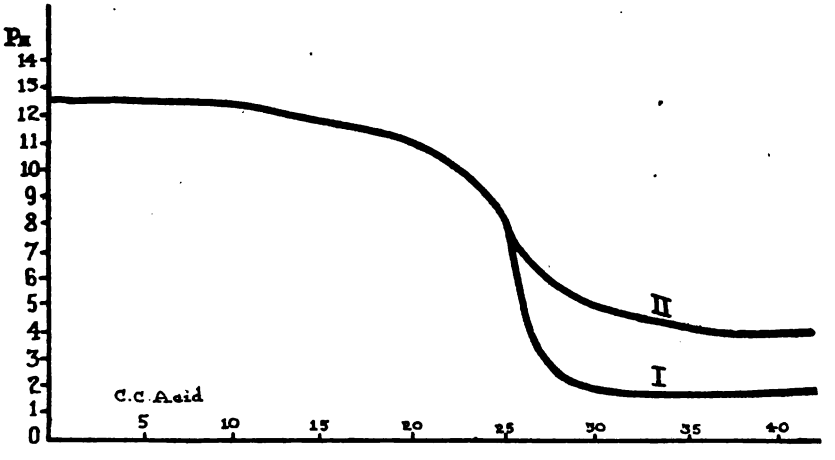

Plate I.

If adsorption is the cause of the effect, there is here no evidence of the adsorption of the hydroxyl ions. On the other hand the results could have been due to the presence of alkaline buffer salts in the charcoal.

These titrations were then reversed, starting with the acid, taking the voltage of Ph. reading, then adding the charcoal and completing the titration with the alkali. On adding the charcoal to the acid a sudden rise in the Ph. reading was noted, the concentration of the hydrogen ions being reduced nearly to the neutral point.

That alkaline reactions are responsible is indicated by the fact that neutralization was complete at about 10 cc. while in the normal curve 25cc. were required. If

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adsorption were involved, the active concentration of ions might have been reduced, but the same amount of alkali should have been required to neutralize the acid.

There is here again no evidence of the adsorption of hydroxyl ions. (Curve IV, Plate III, shows this curve.)

Upon examination of this charcoal it was found to be very impure, containing considerable ash, and when treated with hot HCl it gave off carbon dioxide, hydrogen sulfide, and probably other gases. The presence of sulfides and carbonates as well as phosphates in the ash would allow an interaction with the hydrogen ions to cause the effect noted.

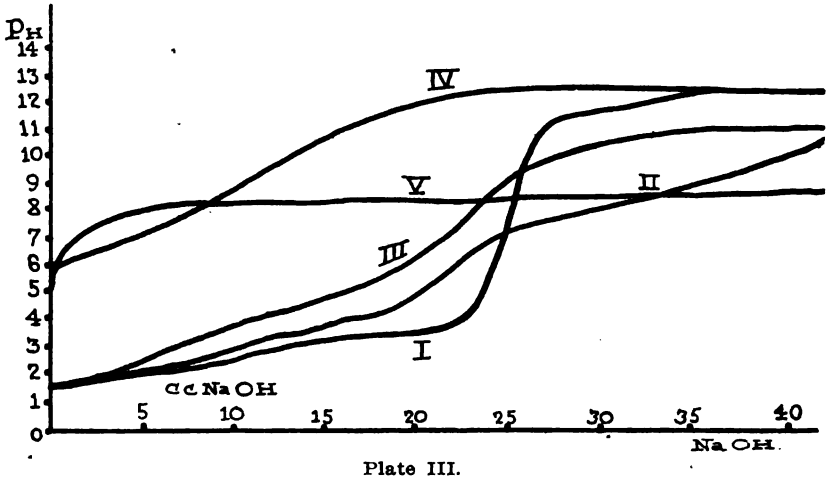

Plate III.

A sample was then boiled with strong hydrochloric acid washed with boiling distilled water and then heated to drive off the adsorbed gases, and a titration was made using one gram of this treated charcoal. The curve is much straighter, the charcoal has no immediate effect, and the curve shows a gradual rise from acid to alkali with no abrupt rise at the neutral point. (Curve IV). This is similar to Bovie's, and seems to show the consumption of both hydrogen and hydroxyl ions. The sample, however, was still very impure, as on burning there was considerable ash present.

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The boiling with acid neutralized the alkaline salts present but evidently did not remove all the impurities, and neutral buffer salts may still have been present.

A sample of "Norit" purified charcoal was then tried in the same way. This gave a very similar curve to the commercial grade that had been treated with acid, except that the curve was slightly lower. This sample was also found to contain considerable ash and was quite impure. (Curve II).

A cample of "Norit" purified charcoal was then tried found to give about the same results as the previous commercial charcoal; however, when tried with oxalic acid instead of rising gradually after neutralization, as with the HCl, upon adding the alkali the first 5 cc. gave a sudden rise, then the curve is held to almost a horizontal line which could only be raised slightly by an excess of alkali. A large quantity of alkaline material was shown to be present since so little alkali was necessary for neutralization. (Curve V).

On the other hand, the failure of the hydroxyl ions to show up may be due to the presence of neutral buffer salts. This curve is also shown on Plate III, Curve V.

Samples of "Super-Filchar", both Pharmaceutical and Sugar grades, were tried with results similar to those of the other purified charcoals with the exception of their being slightly acid in their reactions.

Both samples contained considerable ash, showing them to contain salts of some kind.

Acids stronger than the N/20 were then tried with the different charcoals. Here it was found that instead of a gradual rise in the curve as with the weaker acids, the curve remained horizontal until near the neutral point, then rose abruptly in a vertical line to nearly the full concentration of the hydroxyl ion, similar to that for the acid and alkali alone.

This action is similar to that of other buffer solutions, such as acetates, and phosphates which do not give a buffer effect with strong acids, and gives rise to the theory that the different reactions caused by the various

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charcoals are caused by the adsorbed salts and gases rather than by the charcoal.

CANE SUGAR CHARCOAL

To prove the theory some charcoal containing no metalic salts was prepared from pure cane sugar, and a two gram sample tried with N/20 sodium hydroxide and titrated with N/20 hydrochloric acid (curve represented on plate VII). This shows no depression of the curve at either end or adsorption of ions, but does show the presence of acids, as the neutral point is reached with about five cc. less acid than when no carbon is used. However, after numerous successive washings with boiling distilled water the curve was made to nearly follow the normal curve. Although it was practically impos-

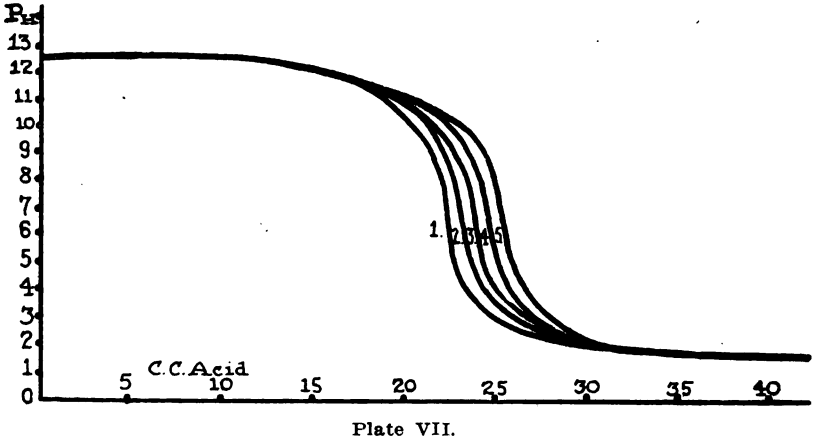

Plate VII.

sible to remove all the adsorbed organic acids from the charcoal by this method, the results of the successive washings show that the change in curve was due to impurities rather than to the charcoal.

To check the work of Bovie a sample of this sugar charcoal was also titrated with solutions of N/100 acid and alkali, and it was found that the sugar charcoal follows the normal curve of the acid and alkali. Samples of the other so-called purified charcoals gave curves very similar to that obtained by Bovie.

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CONCLUSIONS

A. H. Clarke defines a "Buffer", or regulator, as any substance which tends to preserve the original hydrogen-ion concentration of its solution upon addition of acid or base, and states that the hydrogen ion concentration of a buffer solution depends upon the disassociation of the acid and base formed by hydrolysis of the salt used. This could not well be caused by pure carbon.

E. W. Washburn (Jour. Am. Chem. Soc. 30-31-46, 1908) states that a solution will automatically keep itself at any desired hydrogen concentration even though small quantities of acid or base be added to it, provided it contains something which will remove both hydrogen and hydroxyl ions when acid or alkali are added to the solution, and states that a solution which contains the salt of a weak acid or base together with an access of the acid or base has the property of automatically maintaining itself at practically constant concentration. He gives a list of acids, including NaH_2PO_4, H_2CO_3, and bases including $Na_2H\ PO_4$, $NaHCO_3$, which will do this. These are the common "buffers".

Charcoal prepared from animal matter, wood, nut shells, or other sources will naturally contain some of these salts together with some adsorbed gases, which cannot be removed by the ordinary methods of purification, owing to the great adsorbant power of the charcoal, and are therefore present in varying quantities in most animal charcoals, which upon addition of the weaker acids or bases will hydrolize to give the buffer effect observed.

From the fact that we are unable to obtain this buffer effect from charcoal made from sources containing no mineral salts, we are led to believe that the removal of ions obtained from the commercial grades was caused by such impurities and not by the pure carbon.

The differences between the various commercial charcoals may be readily noted from the curves.

The writer wishes to express his appreciation of the help and criticism of Dr. G. L. Wendt, in the preparation of this paper.

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A METHOD OF DETERMINATION OF DIELECTRIC CONSTANTS

A. P. Carman and G. T. Lorance, University of Illinois

Use has been made of the arrangement of oscillating currents described by J. J. Dowling in his article on "The Recording Ultra-Micrometer" in London "Engineering" for September 30, 1921. In this method the variation of the anode current of an oscillating electric valve is measured by a sensitive galvanometer and a curve is drawn showing the relation between the variation of this current and the change in the capacity in the circuit. A part of this curve is practically a straight line, so that a small change of capacity due to a change of dielectric in a condenser can be read off directly from the curve. We have been able to show the difference in capacity in an air condenser produced by exhausting the air; that is, the method is capable of measuring the dielectric constants of gases. It is proposed to measure the effect of pressure on the dielectric constants of gases, the constants of various solid and liquid dielectrics, and the effects of various changes in the dielectrics.

Laboratory of Physics
University of Illinois
March 30, 1922

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THE EFFECT OF SHORT ELECTROMAGNETIC WAVES ON A BEAM OF CATHODE RAYS

C. J. Lapp, University of Illinois

SYNOPSIS

Much has been written concerning discontinuous wave fronts of electromagnetic radiation. Sir J. J. Thomson and A. Einstein have definitely developed such theories. As an experimental test, apparatus[1] was devised by means of which electrons were projected through a compact beam of radiation, such as ultra violet light or X-Rays. In order to magnify any possible effect the electron beam was twisted into a long spiral of about 3 cm. pitch and 1.5 cm. mean diameter, by means of a strong magnetic field. The helical beam thus formed was about 70 cm. long, and the path of each individual electron much longer. If the electron beam was permitted to fall on a photographic plate, traces made on the plate when the radiation was turned off should be different from those made when the radiation was present if any effect occurred. The results recorded photographically may be summarized as follows:

1. When a strong beam of radiation of wave lengths from 8000 to 1300 Angstrom units fell across a stream of rapidly moving electrons, there were indications of a slight decrease in the velocity of the electrons. This effect, however, was smaller than the errors of measurement.

2. With the above radiation wave lengths the evidence is very strong that there was a scattering of the electrons in the beam.

3. When hard X-rays were used instead of the radiation given in 1, there was a distinct decrease in the velocity of the moving electrons, as is shown by the decrease in the diameter of the electron trace.

4. It was also found that X-rays caused a decided scattering of the electrons in the beam.

1. J. J. Thomson, "Electricity and Matter", Ch. 3, pp. 53-70; Phil. Mag. v. 335, Feb. (1910).

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INTRODUCTION

Some years ago J. J. Thomson advanced a theory of light which had properties characteristic of both the emission theory and the usual form of the undulatory theory. While lecturing in 1911, he proposed as an experimental test to the theory that if a stream of electrons had a strong beam of light thrown directly across their path slight deflections of the electrons might be expected. C. T. Knipp,[1] who was a student with Thomson at the time, saw the possibilities of such a research and soon after his return to Illinois attempted the experiment. He used a cathode beam twisted into a spiral, by means of a magnetic field, which fell on a photographic plate leaving a trace in the form of a circle. Although much work was done at that time by Knipp and later by O. A. Randolph (1912), and also by C. F. Hill (1915), yet the difficulties of obtaining high vacua, together with the great mechanical complications, prevented conclusive results from being obtained.

Owing to the fact that since that time some prominent physicists[2] have modified their views concerning the electromagnetic theory of light[3] and much has been written concerning non-continuous electromagnetic wave fronts, it was thought that it might be profitable with the modern methods of producing high vacua to carry forward the experiment. To that end the old apparatus was redesigned and entirely rebuilt in an attempt to determine whether or not electromagnetic radiation has an effect on rapidly moving electrons when thrown across their path.

DESCRIPTION OF APPARATUS

The general arrangement of the apparatus is shown in Fig. 1. The electron discharge chamber was constructed from a cylindrical glass jar 9.2 cm. in diameter and 76 cm. long, inside measurements. A powerful mag-

1. C. T. Knipp, Phys. Rev., Vol. 34, p. 477.
2. H. Bateman, Phil. Mag., Vol. 250, p. 405 (1917); A. Einstein, Phys. Zeitschr., V. 18, p. 121, (1917).
3. J. Kunz, Phys. Rev., 2d Ser., V. 3, p. 464; J. J. Thomson, Proc. Camb. Phil. Soc., V. 14, p. 421, Presidential Address, Brit. Assoc., Winnipeg (1909), Phil. Mag., Feb. (1910), Oct. (1913); H. S. Allen, Phil. Mag., Oct. (1921), p. 523.

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netic field was produced by an electric current flowing through a solenoid on the outside of the chamber. The electrons were obtained from a microscopic spot of oxide deposited on a platinum strip.[1] When the magnetic field was on, and the electrons were projected at an angle with the axis of the tube, they were twisted into a spiral

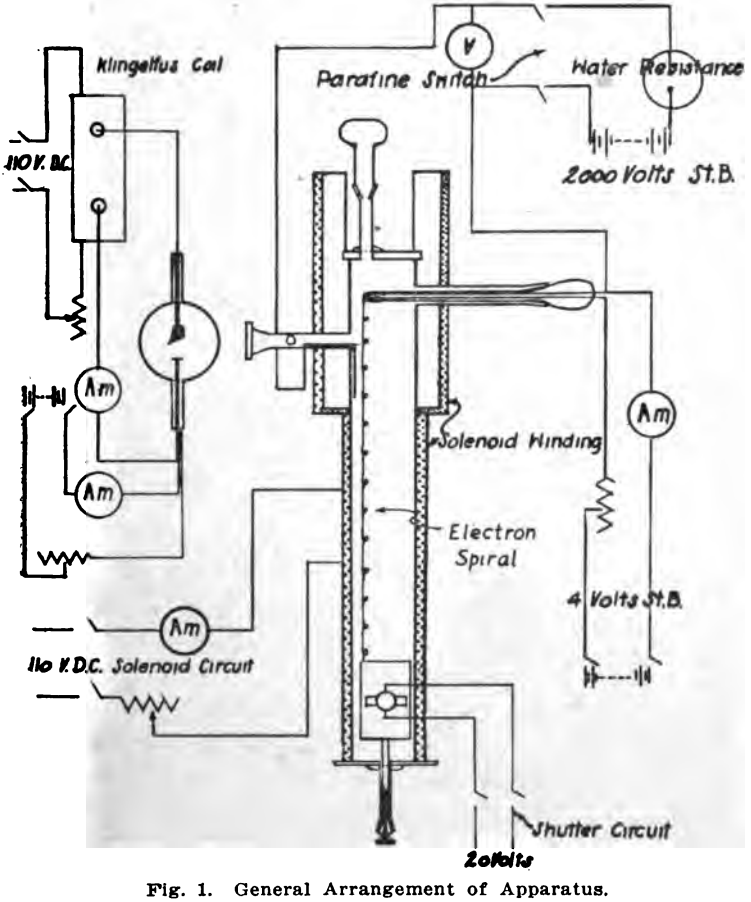

Fig. 1. General Arrangement of Apparatus.

which struck on a photographic plate at the opposite end of the discharge chamber.

The radiation used in the experiment was admitted just in front of the cathode through a side tube with a quartz window and thrown directly across the path of

1. C. J. Lapp, Trans. Ill. Acad. Sci., V. 14, p. 305.

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the moving electrons. Two sources of radiation were used,—a ninety degrees carbon arc, and a Coolidge X-Ray tube. They were placed about 40 cm. from the beam of electrons upon which the radiation was to fall. The X-Ray tube used was the universal type Coolidge tube with a broad focal spot. This was excited by a Klingelfuss induction coil with a six-inch spark gap. The electron beam was maintained by a potential difference of about 2,000 volts from a small high potential storage battery.

A camera was placed within the discharge chamber at the end opposite the cathode and connected through a ground glass joint to the outside in such a way that the photographic plate could be rotated, making it possible to take six exposures on a single plate. The camera shutter was operated by a magnet, but was designed so that the time lag between the tripping and the opening of the shutter permitted the magnetic effects of the operating magnet to disappear before the photograph was taken.

III. OPERATING CONDITIONS

Due to the fact that the experimental operations of this research were very critical, the exact conditions under which the results were obtained are definitely stated. The vacuum was always 0.00001 mm. of mercury or less when the exposures were started. At the end of a series of exposures the pressure was measured and it was seldom higher than at the beginning. The discharge chamber was freed of water and mercury vapors by a P_2O_5 bulb, a large charcoal bulb, and a liquid air trap, the last two being immersed in liquid air.

The Wehnelt cathode was heated to a temperature gained by experience until a beam of electrons of sufficient intensity was obtained to make an impression on the photographic plate. Because of the high vacuum used and the absence of any trace of mercury vapor, it was sometimes very difficult to start the discharge even on the application of 2000 volts. It could, however, usually be induced to start by heating the cathode very

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hot for an instant. After the beam was started the cathode was rotated until it was projected against the side of the tube. When the current was turned on in the solenoid circuit, the beam was caught in an intense magnetic field and wound into a spiral which traversed the length of the discharge chamber, striking on a willemite screen on the outside of the camera shutter.

The intensity, size, shape and position of the phosphorescent spot could be changed by adjusting or regulating the pitch of the cathode ray spiral, the temperature of the hot cathode and the solenoid current. A focusing coil enabled the final adjustment to be made, after which a series of photographs were taken.

Six photgraphs were taken on each plate. A practice was made of taking the odd numbered exposures without, and the even numbered ones with the radiation falling on the electron spiral. The time between exposures was five to six seconds.

IV. MEASUREMENTS

After the photographic plates had been developed and numbered, they were carefully examined to see which ones could be subjected to measurements. A plate, to be of value for measuring, had to possess certain qualifications adopted as standard. First, the electron trace had to be of sufficient intensity to be seen easily with the naked eye, since faint traces could not be seen under the microscope used in measuring the photographs. Second, the trace had to form an arc of a circle of sufficient length to measure its diameter. Third, the edges of the circle had to be sharp so that the error in measurement might be small. Fourth, the six traces on a plate had to be similar so that corresponding measurements could be taken on each one.

A short table has been prepared as typical of the total results from data taken from consecutive plates. In this series the electron beam making the traces was alternately exposed to hard X-Rays. Fig. 2 shows Plate No. 720 listed in Table I.

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TABLE I.

Plate	Electrode Voltage	Cathode temperature	Vacuum in mm. Hg.	Effect	Scattering
710	.....1800 Volts	900°C	0.00001 mm.	Positive	Yes
720	1900	1150	0.00001	Positive	Yes
730	2100	1150	0.00001	Positive	Yes
740	.....Plate was a blank				
750	2000	1150	0.00001	Positive	Edges fogged
760	2000	1150	0.00001	Positive	Yes
770	2050	1150	0.00001	Positive	Edges fogged
780	2000	1150	0.00001	Positive	Yes
790	2000	900	0.00002	Positive	Yes

When the even numbered circles—those taken with the radiation turned on and numbered 2, 4, 6—have a smaller average diameter than the odd numbered ones—those taken while radiation was off—the effect is defined as positive. This decrease in the diameter of the electron traces on the photographic plate is due to a collapsing or a falling together of the spiral. This is caused by a decrease in the velocity of the electrons in the beam. The effect is noted in the fourth column of the table above.

Another effect is present, that is, a scattering of the electrons or a diffusion of the electron beam. This effect, which shows mainly on the edges of the traces, can be noted even when the traces are not complete circles. When it is present the table indicates the fact by "yes" in the last column. Plates 750 and 770 were so imperfect that the effect was covered up, hence no record was made for them.

A large amount of data was also taken where radiation of wave lengths from 8000 to 1300 Angstrom units fell across the stream of rapidly moving electrons. There were indications of a slight decrease in the velocity of the electrons. This effect, however, was smaller than the errors of measurement. Evidence of a scattering effect when the above radiation wave lengths were used was very strong.

At the time the photographs were measured, the data were put into graphical form in order that they might be easily interpreted. Because the time intervals between exposures were approximately equal, the diameters of the circles have been plotted as ordinates, while

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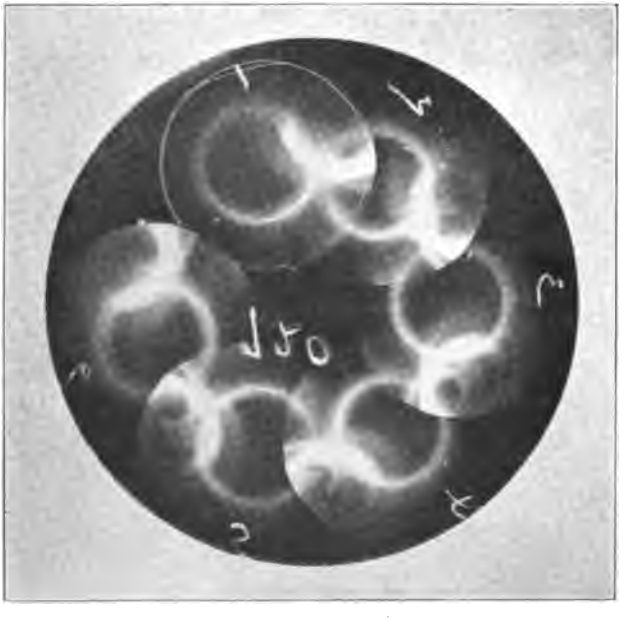

Fig. 2. Plate No. 720, Showing the Difference in the Diameter of the Electron Traces.

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the traces numbered 1, 2, 3, etc., have been used as abscissae. Two of these graphs have been selected as typical and are shown in Fig. 3 and 4.

V. DISCUSSION

No formal attempt will be made to explain from a theoretical point of view the results obtained in this research. It seems, however, that it would not be out of place to suggest possible lines along which explanations might be found. Thomson remarked when he suggested

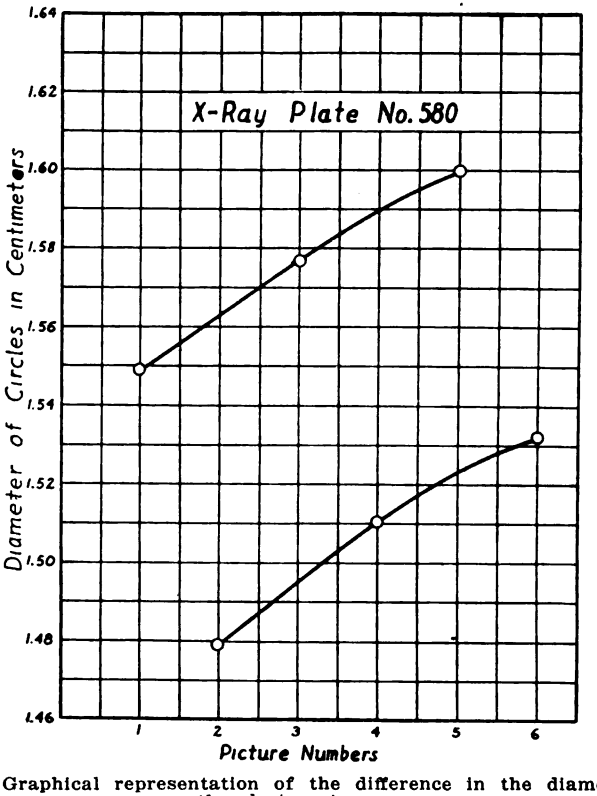

Fig. 3. Graphical representation of the difference in the diameters of the electron traces.

the experiment, that if a diffused pattern of the electron trace was found when radiation was thrown across the path of the electrons, the result might be taken as indicative of the correctness of a theory of light which he had advanced. Einstein[1] has developed another electro-

1. A. Einstein, Phs. Seitschr., V. 18, p. 121.

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magnetic theory along the same lines. In fact, if any kind of a wave theory is postulated in which the wave front is discontinuous, it is evident at once that an appreciable scattering effect would be expected under the condition of the experiment.

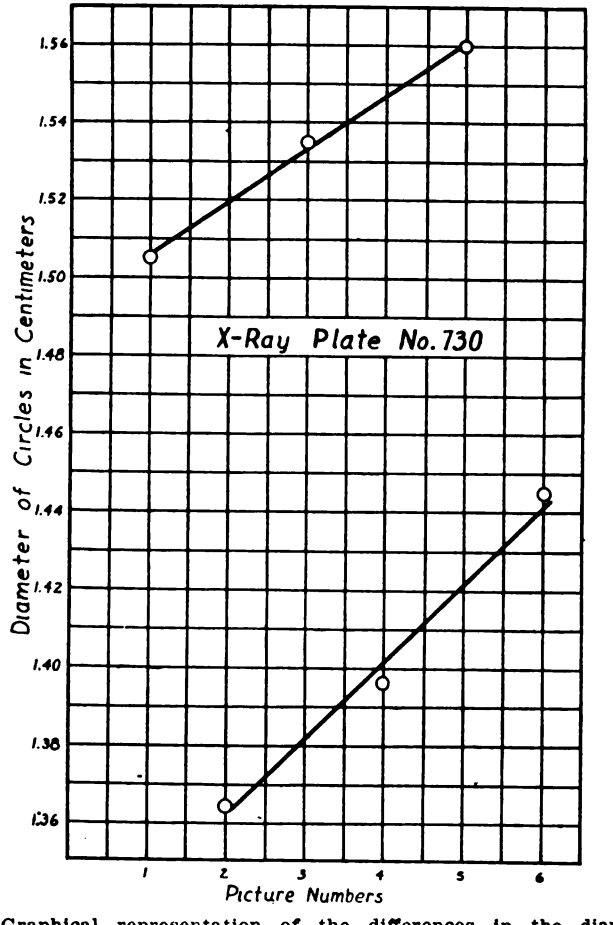

Fig. 4. Graphical representation of the differences in the diameters of the electron traces.

Why the velocity of the electron should be decreased when they pass through short electromagnetic waves is difficult to see in the light of our present theories. So far as is known, the usual form of the undulatory theory cannot give an explanation.

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In conclusion, the author wishes to recognize the help received from the early work of Professor C. T. Knipp on this problem, and to express his thanks to him for his advice and aid throughout the research, and to Professor A. P. Carman for the facilities of the department.

Laboratory of Physics
University of Illinois
May, 1922

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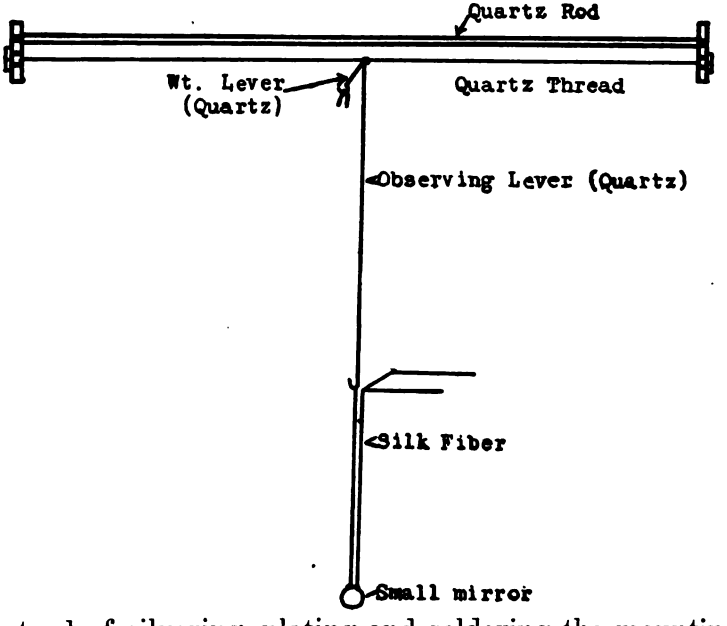
EFFECT OF LUNAR GRAVITY UPON A QUARTZ THREAD BALANCE

R. C. Hartsough, Illinois Wesleyan University

The construction and description of the apparatus. The construction of the balance is somewhat after Threlfall's "Gravity Balance." The chief addition is a long vertical lever arm and suspended mirror for magnifying small movements. This is due to Lord Kelvin in his "Lunar Disturbance of Gravity" experiments.

The shape of the apparatus is of a large T; the horizontal part is 60 cm. long and the vertical part is 50 cm. long.



Instead of silvering, plating and soldering the mounting of the quartz thread, type metal was found entirely satisfactory and much surer and quicker of application.

These specifications, together with the following drawing of the apparatus, will give a correct idea of the balance as used.

Size of quartz thread.....	0.04	mm. diameter
Length of quartz thread.....	55.7	cm.
Length of short weight-lever.....	2.0	cm.
Length of long observing-lever...	26.5	cm.
Weight on weight-lever.....	0.10	gm.

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Five complete twists were given each end of the quartz thread in order to hold the weight-lever horizontal and the observing lever perpendicular.

The apparatus was enclosed in a T-shaped tube of brass and was evacuated to 0.03 mm. mercury pressure, and dried with phosphorous pentoxide. The apparatus was placed in the basement on a solid base; however, passing trucks gave a very noticeable vibration. The temperature of this room was constant to within one degree in 24 hours. A galvanometer telescope-scale was used for observing deflections. Distance was 60 cm. The following readings and curve are typical of many taken.

Date	Time	Scale	Room Temp.	Remarks
Nov. 7	7.30 AM	23.2	19.0°C	
	8.45 AM	26.7	18.5	
	12.00 Noon	22.0	19.0	
	2.30 PM	19.2	19.2	
	5.30 PM	17.4	19.4	
	6.00 PM	16.6	19.5	Moon at zenith 6.12
	6.14 PM	15.9	19.5	
	6.20 PM	15.8	19.3	
	8.00 PM	16.1	19.8	
	8.15 PM	16.5	19.8	
Nov. 8	6.30 AM	22.7	19.3	
	8.00 AM	23.5	19.2	

The evidence of this experiment shows that if the earth's gravitational force is balanced against the torque in a quartz fiber, the moon will disturb that balance gradually over 24 hour periods. A maximum decrease of the earth's gravitation occurs with the moon at its upper culmination and a minimum at the moon's lower culmination.

The author expects in the near future to try to detect any lag effect in the gravitation of the moon and the sun. Of course many changes will be necessary to adapt the apparatus to such measurements.

The facilities of the Laboratory of Physics of the University of Illinois through the courtesy of Professor A. P. Carman were placed at my disposal for this investigation, while the council and help of Dr. C. T. Knipp were a large factor in its success.

Laboratory of Physics
University of Illinois
September, 1921

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ILLINOIS COAL AS A SOURCE OF SMOKELESS FUEL

S. W. Parr, University of Illinois

Until recent years the topic of coke and its production carried with it in America substantially no accessory thought or idea except the simple one of metallurgy, and to all intents and purposes coke in its original significance meant pig iron. Indeed, in a general way we measured our coke production in terms of pig iron, pound for pound. A ton of coke meant a ton of iron, or a ton of iron meant a ton of coke.

Recently, however, we have had somewhat rudely thrust upon us a number of related subjects such as tar and toluene, dyes and drugs, synthetics without number, some with notable and some with ignoble propensities, and then still more recently fuels—fuels of the fuel oil type, fuels of the motor spirit type and perhaps, most interesting of all, fuels of the gas type, in which there is neither ash nor clinker, neither smoke nor soot, until, possibly because the wish is father to the thought, we imagine we can catch occasional visions of fuel gas as the predominating feature, and drugs and dyes and tars and even coke itself as merely by-products in the process of gas manufacture. It is a fascinating program and indeed one not without a very considerable amount of logical environment. So if there is reason in it with the premises fairly grounded in scientific fact, we may perchance be headed for "Spotless Town" without our really knowing it. Evidence toward this end may be somewhat scant or lacking or even possibly of a negative sort. If, perchance, there is any virtue in the old saying that it is darkest just before daylight, then a cursory glance at window sills and curtains and draperies will justify us in thinking that from the standpoint of the old adage at least, the daylight must be pretty close at hand. However, of a somewhat more positive character we may note that the American Gas Association has a standing committee on the Complete Gasification of Coal, and

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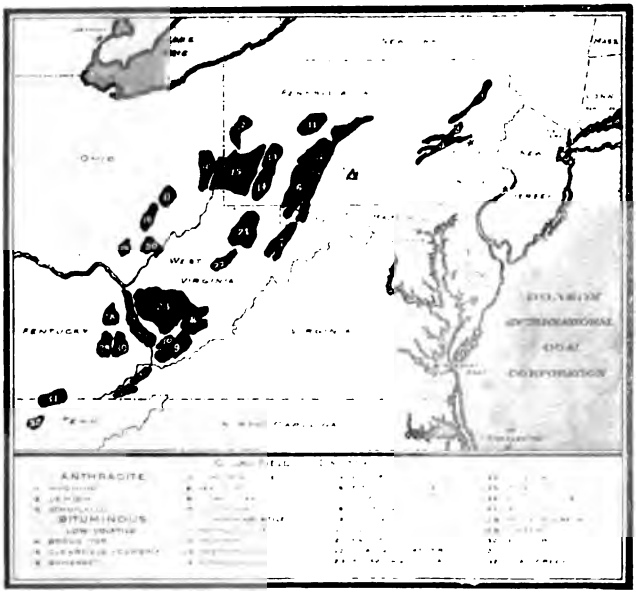

FIG. 1. Distribution of Coal in Eastern United States.

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in France, Rene Masse proposes* that fuel in the gaseous form only be allowed, and that the use of solid fuel in any form whatsoever be prohibited. The argument for such a regulation moreover is not based as might be supposed upon artistic or sanitary considerations, but is advocated strictly as a conservation measure, to extend the life of the coal resources of France. Again, Samuel Wellington of England says** "From the analysis of thermal efficiencies given, there is every attraction for the consideration of the claims of gas as a profitable process in the conservation of coal for whatever purpose it is required."

Indeed, we are even now approaching a state of mind where it may be considered in place to revive the frequently quoted paragraph from an address by Sir William Siemens, delivered in 1881, wherein he says:

"I am bold enough to go so far as to say that raw coal should not be used as a fuel for any purpose whatsoever, and that the first step toward the judicious and economic production of heat is the gas retort or gas producer, in which coal is converted either entirely into gas or into gas and coke."

But whatever the ultimate goal of accomplishment, it is very self-evident that coke is one and the most important of the way-stations. We will do well, therefore, to give more than passing attention to that topic. What is coke? Where does it come from? How is it made? Now we will find at the outset that we cannot go far toward an answer to any of these questions without raising the same question with regard to coal, namely, What is coal?—Where does it come fro?—How is it made? We at once begin to see something of the magnitude of the task set before us. Only a few of the more salient points, of course, can be touched upon within the limits of a single discussion of this sort, and then only for the purpose of maintaining a certain sequence upon which a better understanding of the final results may be based.

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*Chemie Indust., 1918, p. 665.
**London Gas World, 1919, p. 405.

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What Is Coking Coal?

Coals of the eastern United States tend to run somewhat in parallel lines, the most easterly being anthracites, then a much longer line of semi-bituminous coals, and then a longer line of bituminous coals parallel in the main to the semi-bituminous fields, extending southward into Kentucky and westward into Ohio.

But the farther west we go the less we hear about coking activities, the great Connellsville region, for example, in southwestern Pennsylvania being the peak of the curve as we go west.

When we take into our vision the coal fields of the entire United States, we note from the standpoint of coking proclivities that the farther west we go the less credit is given the coals for the purpose of coke making. This is entirely consistent with our technical literature which relegates all these coals to the non-coking class which have a hydrogen-oxygen ratio of 60 per cent or less. The ultimate verdict vitally affects the vast coal fields of the mid-continental region as well as not a few extensive areas in Colorado and Utah, and in the great Canadian Northwest.

This is a rather serious matter for these regions, if it truthfully represents the situation. According to the map, showing the coal areas of the United States, one is impressed with the relative extent of the deposits, especially in comparison with the areas furnishing the coking coals of the eastern United States. Moreover, we were forcibly reminded during the war of the economic waste involved in long freight hauls that could be avoided. One steel works alone near Chicago producing less than 1/8 of the iron of that district uses a train load of coke per day. This would mean, let us say, three trains coming and three trains going, or six trains under constant movement to keep up that one supply. It is 460 miles from Pittsburgh to Chicago. It is, say, 100 miles from some of the principal Illinois fields to Chicago.

It should be stated at the outset that reference is here made to Illinois coals as a type rather than a product

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having geographical limitations. It is to be so considered in this discussion, and as a matter of fact the characteristics as to high oxygen and non-coking character according to present standards would cover also the deposits in Indiana, western Kentucky and the coals of all the states west of the Mississippi from Iowa to Oklahoma.

The importance of determining the really correct status for these high oxygen coals is further emphasized when we note the relative coal reserves of some of the principal producing regions. Colorado would seem to lead the list. But so much is inaccessible owing to the great depth of the deposits below the surface, that for purposes of this discussion, the Colorado reserves might for the present at least be set aside or given a lower place in the list. It would appear then that Illinois leads even West Virginia and Pennsylvania in the matter of potential quantity. The coal in this region is readily accessible, is mined with comparative ease and is contiguous to great industrial centers. Its relative value as an asset to the resources of the state is a matter of great importance. Similar statements would apply equally to the adjoining states where the same coal measures are met with.

So far as ordinary everyday purposes are concerned, it can be shown by reference to a chart on production that aside from the particular adaptation to coke making, these coals are entirely on an equal plane with the coals of either West Virginia or Pennsylvania. For example—suppose we cut off from Pennsylvania the coal output which is mined for the purpose of cokemaking. The remaining tonnage will very well represent the relative rank of the several states with respect to their coal output for general industrial purposes. The annual output of coal for coking purposes is in round numbers about 65,000,000 tons. If we subtract that entire tonnage from the Pennsylvania yield of bituminous coal, the remaining 100,000,000 tons or less just about equals the annual Illinois output.

So much for the lay of the land. Now what is coal anyway?

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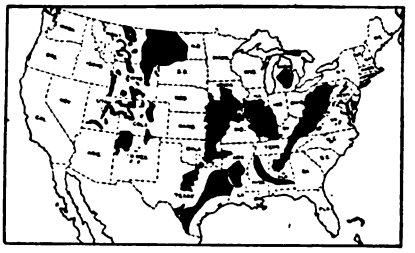

FIG. 2

Known Coal Areas of the United States.

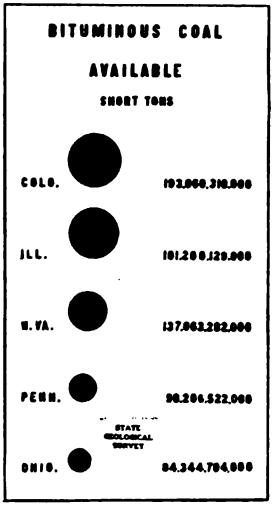

FIG. 3

Relative Coal Resources of Five States.

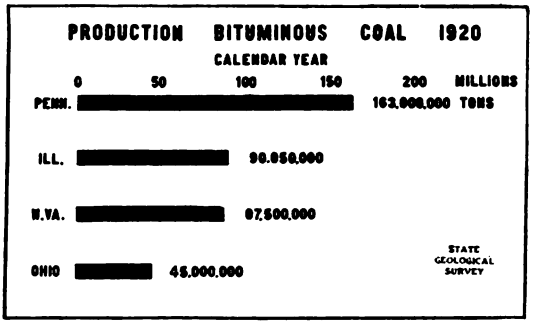

FIG. 4

Coal Production of Four States for 1920.

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COMPOSITION OF COALS

This question was first installed, so to speak, in the chemical laboratory at the University of Illinois in 1902, and it is no exaggeration to say that today in this year of grace, 1921-22, it is more installed than ever. The slight hitch which occurred 20 years ago in the curve for the output of anthracite means that for the major part of that year the country at large was deprived of its smokeless fuel, and dire necessity was the mother of the practice of burning bituminous coal. Hence, the question, "What is coal?"

We have already seen that geographically the Illinois fields are about midway between the deposits of the East and the West. In a general way this is true also geologically. The fact is still further emphasized when we look at the coals chemically. In this chart, we have average

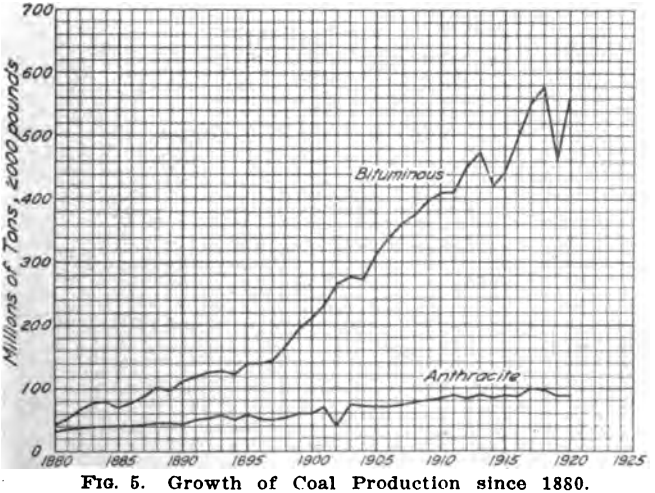

FIG. 5. Growth of Coal Production since 1880.

analyses showing the composition of three types, a low volatile Eastern bituminous coal, an Illinois coal and a lignite. For our purpose in this discussion it is desired to call attention to one characteristic difference only, that is the shaded portion. This represents the residual oxygen or "hydroxy" compounds which remain from the initial organic material after all the vicissitudes of decay and geological alteration have taken place.

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The chart is interesting because it illustrates at least the chemical method ordinarily employed for determining whether a given coal would coke or not. For example, if the ratio of hydrogen to oxygen is 1:1 or even ¾:1 or 75 per cent of the oxygen percentage, then the coal is considered to be in the coking class. But if the ratio of hydrogen to oxygen is, let us say, 0.6:1, that is 60 per cent or less, then the coal is classed as non-coking. When one insists on a definition of these terms from those who make use of them, their answer really amounts to this: "A non-coking coal is one which is not being coked." They do not say it is one that cannot be coked, hence, fortunately the door is left open for the foolish to venture in.

For a better emphasis upon this oxygen factor, to be discussed presently, let us make a new set of ratios from these charted values,—a ratio of the inert or oxygen compounds to the volatile combustible residue, not because we wish to introduce a new ratio as a coking index, but simply as emphasizing from another angle the oxygen content of these coals. Such ratios would then appear as follows:

(1) 4:14, or approximately..... 30%
(2) 14:21, or approximately..... 60%
(3) 21:20, or approximately.....100%

From the standpoint of the usual classification, those coals which pass beyond a ratio between the oxygen compounds and the hydrocarbons or volatile combustible of 1:2 or 50%, bring us into the class of non-coking coals.

It will be evident at once that we have here no explanation whatever as to the reason for coking or non-coking properties. The use or status to be given to analytical results of this sort is that of a definition only. It is a definition moreover which is not even empirical in its derivation. The most that can be said of it is that its basis is that of a coincidence—and any case which might arise to break the coincidence would vitiate the value of the definition.

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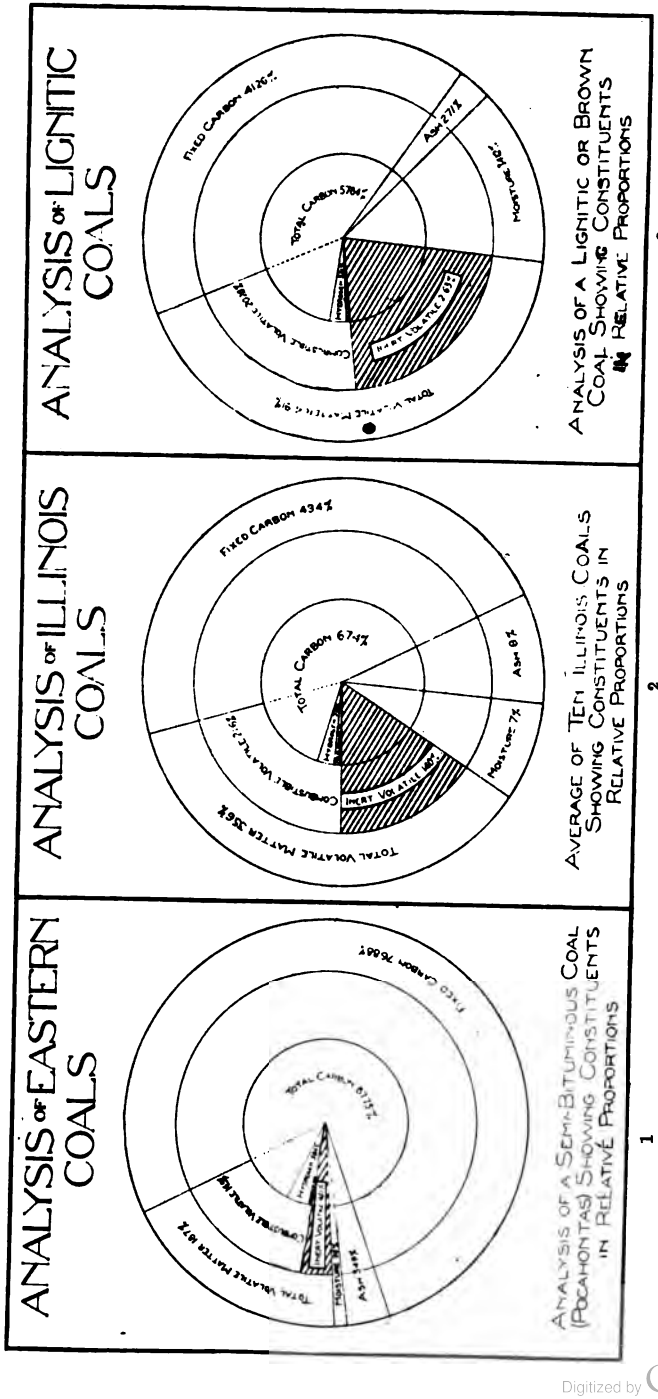

FIG. 6. Analysis of Typical Coals.

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This brings us directly to the question as to what is involved in carbonization—and by carbonization is meant not simply the destructive distillation of organic matter but the production at the same time of a strong dense coherent mass, capable of being handled and suited for use in either domestic or industrial appliances. Are there any underlying principles which play a fundamentally important part in the production of coke? In other words, is there a theory of carbonization applicable in a general way to coals of all types, the recognition or observance of which would enable us to attain the utmost limit of possibility in the matter of coke formation?

Let us review some of the existing theories. In the old beehive oven the coal having a depth on the floor of the oven of about 3 ft. was decomposed by the heat of the burning gases which were discharged from the coal into the upper part of the chamber. As the decomposition proceeded downward, the gaseous products of decompositions were obliged to pass upward through the highly heated layers, thus undergoing secondary decomposition. The carbon deposited on the surface of the coke in this process of decomposition gave a silvery lustre and was believed to play a part in the formation of the cell structure of the product.

Now, this is hardly to be credited with the designation of a theory. It is doubtless a description of some things that take place upon or around the coke after it is formed. It is distinctly silent as to what is going on down in the coal mass at the zone of active decomposition. The fact of the matter is that the coals worked upon in this fashion were for the most part from the Connellsville region, and would be entirely indifferent as to what theory was proposed for their coking property. They would coke just as well under one theory as another or under no theory whatever.

EFFECT OF OXYGEN ON COKING

We come next to a study of coals resulting from the use of solvents which separate the coal without decompotition into two portions, one of which has distinctly non-

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FIG. 7. Beehive Coking Oven.

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coking and the other has distinctly coking properties. We have here the first real forward step in the study of the carbonization. The results obtained by these methods were well summarized by the late Professor Vivian Lewes in his Cantor lectures delivered in London in 1911. He called the non-soluble, that is the non-coking substance, the degradation product of cellulose or cellulosic residue, and soluble, or coking substance, he called resinic material. In the light of present-day studies, these names are not happily chosen, but that fact does not interfere with the value of the method itself. A continuation of this line of investigation is being very ably carried on by Professor Bone of London and by Professor Wheeler of the University of Sheffield.

In our own laboratory at the University of Illinois, it continues to be the most prolific source of information and furnishes the most numerous avenues of approach to the fundamental characteristics of these two type substances. It is along these lines, moreover, that we have made the most encouraging progress in our studies as to the underlying principles involved in the carbonization of coal.

It will be altogether impossible to go into a detailed discussion of the facts which have been developed, not only because there are so many of them, but also because there are so many which are in process of development and have not yet reached full maturity, and the plucking of immature fruit of this sort is not conducive to mental health and tranquility.

A few points, however, will give a general idea of what has been accomplished.

In the chart here shown, we have an illustration of the two type substances, the larger amount being the insoluble residue or non-coking substance and the smaller portion being the so-called resinic or coking material. The amount in each sample will give also a general idea of the relative proportion of these two substances as found in Illinois coals.

Now from the discussions that have thus far been presented in the literature, it would appear that the soluble material at the right, Fig. 8, is looked upon as

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the active coking constituent and that the insoluble material or cellulosic residue is inert, and when it does not predominate in too great an amount over the soluble material, a good coke results. In this view of the theory of coke formation, the active coking material, the soluble or so-called resinic bodies, plays the part of a binder to the non-coking portion.

This theory would seem to have substantial confirmation by so simple an experiment as the following: Suppose we take a sample of the original coal of the type here used and coke the unaltered material in a crucible according to the ordinary procedure for the determination of volatile matter. We shall obtain a sample of normal coke such as this particular coal may be expected to produce. If now we take these type substances as illustrated in Fig. 8 and reassemble the non-soluble or cellulosic residue with the proper proportion of the coking substance, we shall have after the carbonizing process again a sample of coke which can in no way be distinguished from the first or normal sample. Hence the demonstration of the simple binding function of the resinic material would seem to be established.

But suppose now we proceed a few steps farther. We know that freshly mined coal has a tremendous avidity for oxygen and that if we permit a finely ground sample of Illinois coal to become fully saturated with that element all tendency on the part of the coal to produce coke is lost. Let us, therefore, saturate a portion of each of these subdivisions with oxygen and recombine them in their proper proportions, and for comparison, to make the circle complete, we will retain the sample already made in which both subdivisions were in the fresh or unoxidized condition. In Fig. 8 we have illustrated on the left, one sample of coke which has resulted from a recombination of the fresh or unoxidized portions in their correct ratios, and at the right we have a sample of coke resulting from a recombination in correct proportions of an oxidized resinic substance with a fresh or unoxidized residue. Note especially that the resulting coke is indistinguishable from the normal sample at the left in the

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FIG. 8. FIG. 9. FIG. 10.

FIG. 8. Coal separated by solution into non-coking and coking constituents. FIG. 9. Samples of coke from original coal and reassembled constituents, the binding substance having been oxidized before combining. FIG. 10. Effect of oxidizing the non-coking residue on coking property of coal.

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figure. This result is quite the opposite from what would be expected. If a coal which has been completely oxidized will not coke, and if the resinic matter carries the coking principle, then complete saturation of the resinic portion with oxygen should destroy its coking or bonding property. But it does not, the resulting sample being indistinguishable from the standard made for comparison.

Now we will reverse the process, saturating the non-coking cellulosic residue with oxygen and leaving the resinic material in the fresh unoxidized state. Upon recombining and carbonizing, we have the result as shown in Fig. 10. Here the coking property has been completely destroyed.

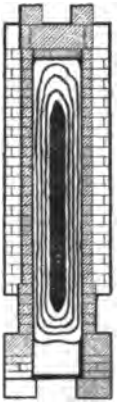

FIG. 11. Progressive Coking Lines in By-Product Oven.

Evidently our theory of the coking process will have to go farther back than the simple idea of a binding material, to a study of the factors that enter into the properties of both constituents and the conditions that affect their modification on the one hand or their preservation and indeed their accentuation on the other. Here it would seem from this illustration that we have worked out an answer to the question how not to make coke instead of the question "How is it made?" On the contrary, it may very well happen that the most direct information as to how to do a thing may come from positive evidence as to how it should not be done.

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By way of illustration taken from some of our experiments: Here is a high volatile eastern coal with excellent coking properties. It has in its normal condition a hydrogen-oxygen ratio of 73 per cent. Now by saturating with oxygen under suitable conditions whereby it has taken up approximately 50 times its volume of oxygen, it has a hydrogen to oxygen ratio of 33 per cent, and has dropped out of the coking class absolutely as we would expect. By suitable procedure, however, and recognition of the part that the cellulosic residue may play in the carbonization process, it is possible to produce a normal coke even from this highly oxygenated sample which, as we have seen, was reduced in its H:O ratio from 73 to a percentage of 33.

LOW TEMPERATURE CARBONIZATION

Space will not permit of details in connection with the behavior and control of these factors. One point of fundamental importance and interest must suffice. It relates to the property of all coals in general and high oxygen coals in particular of decomposing with the evolution of heat. The interactions involved, therefore,

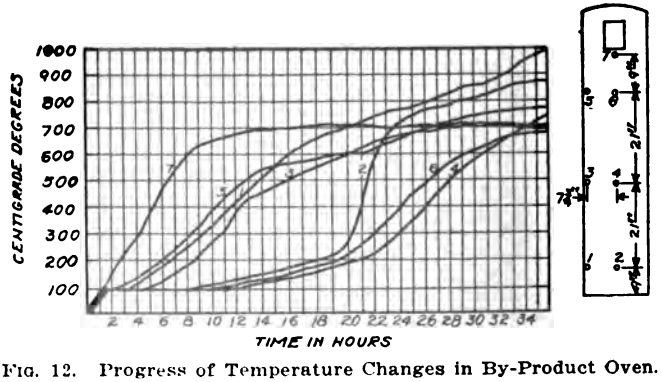

Fig. 12. Progress of Temperature Changes in By-Product Oven.

which it is essential to control, are exothermic in character. This fact should be coupled with another important one, namely, the control of these interacting substances can best be carried out under low temperature conditions of carbonization, that is, at temperatures below approximately 750 deg. C. (1382 deg. F.).

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Fortunately for our purpose this fact of exothermicity and of carbonization are not only compatible with each other, but we believe are essential to the successful accomplishment of the prime purpose we seek, namely, the carbonization of high oxygen coals.

In attempting to maintain low temperature conditions, the first problem with which one is confronted is the physical impossibility of conveying heat into the center of a non-conducting mass without maintaining at the exterior a high heat head for the purpose of driving the heat forward through the insulating layers of coke that are continually in the process of formation. Some idea of the actual conditions involved may be seen from Fig. 12 here presented. The diagram at the right is a cross-section of a by-product oven with points indicated where temperatures within the coking mass were taken. It will be seen that in an extended 35-hr. coking period, the temperatures at the center of the mass did not reach the stage of decomposition, say 250 deg. C. (482 deg. F.) until after 20 hr. The obtaining of heat transmission, therefore, by simple process of conductivity is at once seen to be impracticable if low temperature conditions throughout the mass are to be maintained. It is at this point that we have attempted to use the exothermic reactions involved in the carbonization process. These exothermic reactions are directly due to the oxygen compounds of the raw coal. By reference again to the chart, Fig. 6, showing the makeup of an Illinois coal, we can at once see the possibility of a very considerable amount of heat available from this source. The high oxygen content therefore becomes an asset instead of evidence of a nullifying influence in the process of carbonization. The direct measurement of this exothermic heat has been one of the most interesting as well as one of the most elusive features of the problems involved. If time permitted it would be worth while to illustrate the methods of measurement employed. It will doubtless be better at this point to follow out the sequence of the process wherein use is made of the exothermic heat and how it is made available.

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Let us assume, by way of illustration, that in the case of an average Illinois coal, we have an amount of this potential heat equal to 4 per cent of the total heat of the coal, or approximately 500 B.t.u. per pound. Now, if we can drop a mass of coal into a retort whose walls are heated to 750 deg. C. (1382 deg. F.) and start off the exothermic reactions in such a manner that they will become autogenous, they will, of course, pass beyond the outer zone of heat furnished from the walls of the oven and proceed to the center of the mass regardless of either the heat head at the surface or the insulating property of the mass.

In the illustration here shown, these conditions have been secured. Note particularly that a narrow zone at the outer rim shows a coke formation which has been due to the direct application of heat from the walls of the retort. Beyond this zone and thus soon out of reach of the exterior heat, the reactions became autogenous and quickly penetrate to the center. Naturally also we would expect that in order to travel alone, they must have at least slight surplus of heat at every stage of progress inward, which would thus be cumulative in effect and to the end of the process would show a higher temperature at the center of the mass than at any other point. This correctly represents the uniform condition at the termination of an experiment. Incidentally, it is interesting to note not only the texture and cell structure peculiar to the carbonization that occurs under these conditions, but also that the sample at the left is from an Illinois coal with the high oxygen value as already shown in the chart, while the sample at the right is from a high volatile eastern coal which would at once be placed among the coking coals because of its low oxygen content. The texture, strength, density, etc., of the two examples seem to be very much alike.

The question will at once arise in your minds as to why this effect is not secured in the regular byproduct coke oven. The wall temperature starts the coal at even a higher stage, say 1000 deg. C. (1832 deg. F.), while we are using from 700 to 800 deg. at the start. Why do not the exothermic reactions occur and travel autog-

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FIG. 13. Samples of Coke from Illinois Coal at Left and Eastern Coal at Right.

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enously to the center in the usual method of procedure? A brief bit of figuring will answer the query. Let us recall that we are assuming a source of heat of this sort equal to 500 B.t.u. per pound. Now if we start out with a mass of coal at 30 deg. C., or say 100 deg. F., and plan to raise the temperature of the mass to 800 deg. C., or 1500 deg. F., we must provide heat enough to raise the mass through 1400 deg. F. Roughly, the specific heat of coal is 50 per cent that of water, hence it will require 700 B.t.u. to do the work of raising the temperature of the mass without taking into account the latent heat of vaporization for the water present. But we have to our credit only 500 B.t.u.; hence, no matter how good a start we give to the reactions, they will cease to operate as soon as we pass beyond the zone of external heat where that effect is lost by reason of poor conductivity. As we say when attempting to start a fire with green or wet wood, "the fire goes out."

On the other hand, if we raise beforehand the temperature of the mass to say 300 deg. C., or 600 deg. F., slightly below the point of active decomposition, the work remaining to be done is now that of raising the temperature of the mass through only 800 deg. F., or in terms of heat units, we require only 400 B. t. u. Since we assume 500 B.t.u. at our disposal and expend only 400, we have a slight margin to our credit which accounts for our cumulative effect and higher temperature in the center at the close of the process.

This, therefore, in a general way sets forth what we believe to be the essential factors that must be taken into account in the coking of high oxygen coals.

A summarized view would indicate that the theory of carbonization needs to be rewritten or revised in such a manner as to cover the case of high oxygen as well as low oxygen coals. That when the factors are thus understood and their influence properly controlled, the so-called non-coking coals may be brought into the coking class, and that the low temperature condition is the one which lends itself most readily to the carrying out of the carbonization process. Perhaps the most important of all is the utilization of the exothermic property

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whereby the slow effect by conductivity is replaced by the relatively quick procedure of preheating the coal, thus securing autogenous chemical reaction throughout the mass.

For the present at least we are content to leave the ultimate goal of fuel gas and stop at the coke stage, especially in view of the fact that the coke produced in this manner comes into the class of smokeless fuels with combustion characteristics quite comparable to the anthracite or semi-anthracite type.

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PAPERS ON GEOLOGY AND GEOGRAPHY

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THE TEACHING OF GEOGRAPHY IN THE HIGH SCHOOL

V. I. Brown, Principal, Watseka Community High School

When I first received from your chairman an invitation to present before this meeting a ten-minute paper, I felt that there had been some mistake. I have had that feeling several times since and find no small amount of the same existing at this moment. Perhaps when I shall have finished you will have a similar feeling. If you do I shall not question your judgment. With this attitude of mind I wrote to a friend who is interested in the teaching of Geography and received the following suggestion. "You may know the character of the meetings to have changed, but at the meetings of the Academy of Science which I have attended all the papers have been on original investigations along scientific lines." I then wrote your chairman and suggested that there might have been an error and that any paper which I might present would, of necessity, be pedagogical rather than scientific. Having his assurance that such a paper would be acceptable and in place, I have made bold to discuss before this meeting "The Teaching of Geography in the High School." I am not a scientist. I have made no original investigation along scientific lines. However, if this Academy is interested in the decline of a subject which should retain a place in our high school Course of Study, a subject which should be a science, but is not as now taught, then this paper may have some slight claim to a place on your program.

An examination of the "Report of the High School Visitor of the University of Illinois for the year 1920-21" shows that of the 530 accredited high schools in the state of Illinois, 413 offer courses in Physiography, and 367 offer courses in Commercial Geography. This means that approximately 70-80% of our accredited high schools offer courses in geography. At the first glance this seems not such a bad showing for the subject; but when we consider that the courses are almost entirely

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elective, that 334 of the schools offering Commercial Geography and 381 of the schools offering Physiography offer but ½ unit, that of the 31 schools offering 1 unit almost 50% are in the city of Chicago, and that the courses are found every where from the freshman to the senior year inclusive, the showing is much less favorable.

To determine the qualifications of the teachers handling the subject and the methods used in teaching would be an interesting investigation. The reports of the attendance of teachers in the Geography Section of the High School Conference for the year 1916-21 inclusive and the report of the Secretary of the Committee on the Appointment of Teachers of the University of Illinois, 1920-21, may serve to indicate something of the conditions. The number of teachers registered in the Geography section of the High School Conference for the various years was as follows:

1916	1917	1918	1919	1920	1921
16	19	8	13	26	25

In every case this is the lowest registration in any section of the Conference and is less than the number of schools offering unit courses.

From September 1st, 1920, to September 1st, 1921, the Committee on the Appointment of Teachers at the University of Illinois received 2079 requests for teachers, of which 1328 were from Illinois. Of these requests only twenty-one included Geography. One was for Geography alone, four for Geography as a major subject, and sixteen for Geography as a minor subject. Of the 220 candidates enrolled with this committee and graduating in 1921, one woman was registered in the Department of Geography and she was placed in either a college or Normal School. The Secretary of this committee reports a total of only two Geography positions filled last year. While this data is not conclusive, it certainly indicates that Geography in the high schools of Illinois is being taught by a group of teachers who are ignorant of both subject matter and method, and who have little or no interest in the subject. Geography in our accredited high schools is a "fill in" subject wished upon

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the unfortunate teacher who happens to be available at the time and place best suited to the daily program. Under such conditions "The Sick Man of the Curriculum" shows no improvement, and we may as well prepare ourselves for the worst.

It is not the purpose in this discussion to defend either the right of Geography to a place in our high schools or the proposition that it should be taught as a science. Both of these things have been assumed. Neither has it been thought necessary to distinguish between Physiography and Commercial Geography. It is believed that the suggestions submitted may be applied equally well in either subject. If, then, Geography is to be taught as a Science, what shall be the method of attack? Psychologically as well as scientifically the pupil should be introduced to the subject matter of Geography through the study of pertinent problems.

These problems may be simple and limited in their scope or they may be as broad as the ability of the class and the nature of the subject matter will permit. Their solutions may come through the examination of subject matter, through laboratory work, or through field trips. The essential thing is that the pupil solve the problem for himself under the guidance of the teacher. Facts, details, definitions, and principles are subordinate to the solution of the problem.

But the lessons will develop certain facts, definitions, and geographical principles which need to become the permanent possession of the pupil in order that they may serve as a part of his working equipment in the solution of further problems. These definitions and principles are a minimum requirement which each pupil should master.

The more enthusiastic advocates of the problem method would have us believe, that the necessity of memorizing and drill cease with the introduction of this method of teaching. But until the Law of Recall shall change, the necessity of drill, like the poor, "ye have always with you." Since these facts, definitions, and principles are to be a part of the child's working equipment they should be, first, scientifically accurate; and second, within the

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realm of the child's experience and vocabulary. Half truths are always dangerous. It is not true that temperature decreases as latitude increases. It is true the temperature tends to decrease as latitude increases. It is a good science to leave a principle in such form that it is subject to enlargement. It should not be left in such form that it becomes subject to correction.

One of the worst faults of our science teaching has been the assumption that Science, to be science, must be abstract and expressed in abstract terms. The following definition occurs in Mill's International Geography, "Geography is the exact and organized knowledge of the distribution of the phenomena on the surface of the earth, culminating in the explanation of the interaction between man and his terrestrial environment." Such a definition may be in place in such a book, but we have carried too much of such so called "scientific language" over from our colleges and universities into our high schools. Geography deals with common place things and phenomena. It should be expressed in common place language. If the solution of problems has developed the necessary facts, definitions, and principles and these have become a part of the pupil's possessions, he now has the tools for attacking larger and more complex problems, each of which may in turn develop new principles.

In order that Geography may be taught in this way, it would be necessary that we have, first of all, a group of trained teachers. This would mean teachers not only familiar with their subject matter but also trained in scientific methods of presentation. The possession of Geographical knowledge is no more assurance of the ability to teach than the mere possession of capital is assurance that the holder is a financier. Second, there needs to be within the State an organized body of teachers who will acecpt the responsibility of guiding and developing the teaching of Geography. Whether or not such a work is within the province of the Illinois Academy of Science, I am not prepared to say. But unless some organized group shall attempt this work, Geography will never play any vital part in the education of High School pupils.

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A FEW CRITICISMS OF THE ILLINOIS STATE COURSE OF STUDY IN GEOGRAPHY

C. E. Cooper, State Normal University, Normal

One of the most formidable arguments with which geographers have to contend is that which claims that the subject has taken so much unto itself that it is a duplication of the work found in a number of other lines of study. Of course one can prove that many of these other subjects which are so closely related to geography are but the off-spring of the parent, geography, but it is not the purpose of this paper to consider either the justice or the fallacy of the suggested criticism. We shall do better to admit that, regardless of the justice or injustice in the criticism, it is usually the best policy to remove the cause of it.

One cannot look carefully through the State Course of Study without being forcibly struck with the needless duplication of the subject-matter in "Home Geography" and "Nature Study and Agriculture". My first criticism falls upon the home geography work of the Fourth grade. Each monthly topic as outlined in the home geography work receives sufficient emphasis somewhere in the work in nature study. At best, only an introduction is needed in such subjects in this grade. Such work as the phases of the moon, a detailed study of the soil, equinoxes, solstices, and much of the star study is away beyond the comprehension of such young pupils. It is unfortunate that the vital and human subject of geography has inherited so much of this work from cartography, astronomy, and mathematics. The best part of the work, as outlined under home geography, is the work on the study of the various peoples. This is the time when children are vitally interested in the children of other lands. If geography is to be begun in this grade it ought to be correlated with language work and should take the form of geography stories. Here is the place to teach where our various foods come from, how they are gotten, and how our homes are constructed, in comparison to the homes of boys and girls in other countries.

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Excursions to stores are very valuable in this connection. This kind of work is not the business of nature study.

Personally, I believe that geography can well afford to turn over to the teachers of nature study and language most of the work as outlined in home geography. There is too great a tendency to crowd geography into the grades below the eighth. I have a letter upon my desk from a teacher of geography in the seventh and eighth grades of one of our smaller villages. She states that her Superintendent is requiring her to teach the seventh and eighth grade work in one year and that he argues that geography contains so much detail that part of the work should be left out anyway. This opinion is all too common. It is a school-room tragedy to see the sixth and seventh grade children struggle with much of the mathematical geography which is outlined for them. Not long ago I watched and listened while an eighth grade class tried to wade through the work as outlined upon the motions of the world and its shape. Their teacher was as well informed as the average grade-school teacher, in this phase of geography. The children "Edisoned" the words, oblate spheroid, aphelion, etc., back to the teacher, but it took only a little questioning to show that the whole story meant very little to them. Perhaps skillful teaching and an extended knowledge on the part of the teacher could have accomplished fair results, but that is, of course, what we do not have in our common schools. Geography must be pushed up through the eighth grade and through a year in the high school, and there is no better way to do it than by permitting nature study to take its place in the lower grades. Geography study calls for mature thought, and we teachers of the subject should seize every opportunity to dignify the work by dropping the duplication and pushing its case into higher courts. On the other hand, nature study should be taken out of the eighth grade and room thus made for geography. Teachers of nature study can afford to do this if they have the extra time of geography elsewhere.

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In the third month of the fifth year the work on the scale of the globe can well be omitted. School-room globes are so small that the equivalent in miles for one inch is too great a distance for children to comprehend. The time can be spent to a much greater advantage in teaching sizes and distances by means of comparisons with which the child is familiar. Nothing is gained at this age by teaching the child that the earth has a circumference of 25,000 miles. You can impress him with its size by finding out how long it would take a train going at an ordinary rate of speed to travel around it, or by some other easy comparison.

The sixth grade is not the proper place for the teaching of much of the detailed work on latitude and longitude. This part of geography should be put off as long as possible in the grades. Positions should be taught by comparisons, rather than by degrees of latitude and longitude. In the list of definitions in the work of the first month I would leave out parallels, meridians, meridian-circle, circular measure, and all of the definitions which follow them. Those terms which we do teach should not be taught as definitions to be learned and parroted in set phrases, but should be taught by illustration.

I am convinced that we are accomplishing little by trying to teach the wind system in the grades. Its place is in physical geography. The students who enter my classes in the Normal, having had no geography since the grades, are utterly ignorant concerning a knowledge of the winds, though some teacher has tried to teach them this work in earlier years. It is not just a case of forgetting because they do not even comprehend the principles of the wind system. I think that we should teach the causes of the winds, but that we should lay most of the stress upon their effects; such as, winds blowing off water, winds on leeward and windward sides of mountains, winds from the north, and winds from the south, etc. No attempt at a classification of the winds should be attempted in the grades. We are interested in the human effects of winds and not a scientific classification

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which is at best only generally true. A classification is of value in high-school years as a means of determining climates but is beyond the comprehension of the grades.

Less stress should be placed upon the climatic influences of ocean currents and more upon the influences of large water bodies. Instead of teachers permitting the children to get out of the grades with the idea that the Gulf Stream is totally responsible for the mild climate of the British Isles, they should bring out more carefully the effects of great water bodies and should show that even if the Gulf Stream were not present, the climate of these islands would still be more moderate than if they were in the same latitude but surrounded by land. The effect of liberation of heat by precipitation should also be stressed.

An understanding of cyclonic and anti-cyclonic winds is hopeless in the grades, is very difficult for the high school, and will keep the beginning college student busy for some time before they are mastered. I have more calls for help from teachers, concerning these winds, than in any other phase of geography. Throughout the seventh grade, more time should be spent upon the effects of rainfall and its distribution and less upon the technical causes of rainfall.

The eight grade mathematical geography as outlined is far too abstract for grade school children. It forces them beyond their ability and tries to give them a body of knowledge which is of value to them only in a cultural way. You may argue that this knowledge is of value to them and indeed necessary for the intelligent reading of the textbook. In answer I would say that too long we have tried to mould children to the form of the textbook written by some college professor who has forgotten that he ever was young and consequently fails to make the textbook meet the needs of the child. I wish that some of the fine women who are doing the critic work in the Normal Training Schools of our country would take up the writing of geography textbooks.

The star work is of course a heritage from astronomy. We should teach what stars are, if we haven't already done so in nature study, and the names and locations of

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those which will assist the pupil in locating himself. Star knowledge which is of a cultural value can be left until more mature years. Just enough should be taught concerning meteors, comets, and shooting stars to remove superstition. In the list of definitions for the first month of the eight grade I should omit the following: point; line; surface; solid; plane; plane surface; arc; ellipse; foci; major axis; minor axis; plane of the earth's orbit; perihelion; aphelion; meridian circle; and oblate spheroid.

It seems to me that there is no use in taking time to prove that the earth is round. Much of mathematical geography must be taught dogmatically, so why try to prove something so obviously true? If some pupil should want to know the proofs, then the fact that men have sailed around it, and the shape of its shadow ought to be sufficient proofs. It is inconceivable that the altitude of the stars and the pendulum proofs are more comprehensible to these children than these simpler proofs.

Similarly the proofs of the rotation of the earth are unnecessary. If they are to be used, the dropping of the ball, Foucaults pendulum, oblate spheroid, circulation of the water and the atmosphere are beyond the understanding of grade-school children. Let us put the emphasis upon the human effects of the shape of the earth and its movements, and worry less about the mathematics of the situation.

I suppose one can teach inclination and parallelism so that the child can give the facts back parrotlike but I doubt very much whether he will understand those facts. Not one student in twenty-five entering my normal-school classes has any knowledge of the width of the zones. Indeed, is it necessary in the grades to give them that knowledge? Why not spend the time to better advantage in teaching them the proportions of the continents in the various heat belts and the effect of these heat belts upon life?

The equinoxes and solstices are confusing and difficult to teach even in high school classes. As for the change of seasons, we should stress their effects more than their causes. A few simple demonstrations of moving the

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globe around a child ought to be sufficient to show him the changing position of the direct rays of the sun. Latitude and longitude should be taught in this last grade but even here much of the detail must be left out. The International Date Line is incomprehensible to grade-school pupils and it takes a clever teacher to make it plain to a high-school class. Pay more attention to comparisons of various places as to latitude and longitude and less to the details of number of degrees, etc.

In short, one can take the mathematical geography as outlined in our State Course of Study and make the average freshman in our normals and colleges work exceedingly hard to master its principles. Much of it does not function in the later life of the average individual.

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THE HENNEPIN CANAL

ROBERT G. BUZZARD, STATE TEACHERS COLLEGE, DEKALB

The present session of Congress is confronted with the problem of an international deep-waterway. The International Commission studying the project of deepening the upper St. Lawrence River has submitted its report. The Congressmen from the Mississippi River valley and the Great Lakes are clamoring for the building of this waterway. The news columns of the cereal region are broadcasting the benefits to the grain grower such a waterway will bring about. From the current propaganda one reads that the problem of cheap transportation eastward will be solved by a thirty foot channel to the Great Lakes. To Chicago, Milwaukee and Duluth will come the seaboard advantages of Boston, New York and Philadelphia. To the student of the transportation problem which has grown with the development of production in the upper Mississippi basin, this clamor for a waterway eastward is but the latest of a series of such agitations. The experience gained through the use of the Hudson River, the Erie Canal, the line of the Great Lakes, the Erie-Ohio canals, the Illinois and Michigan Canal, and the other waterways which aided the move of population westward, seems to have left indelibly impressed on the minds of succeeding generations the conception that waterways are the solution of all transportation problems.

Within the bounds of our own state lies a not long since completed example of the application of waterways to the problem of inland transportation. Its conception, the fervor of its agitation, the marked distress of the region demanding it, the stick-to-it-iveness of the Congressmen who made it a plank in their platforms, the twenty-seven years of heckling before Congress succumbed, the building of a waterway for a people who had forgotten or had never known why it was wanted, its maintenance amid their hard roads and efficient railways, — in all this the Hennepin Canal exemplifies the effort our national government is putting forth towards solving in-

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land transportation. The story of its achievement is worthy the notice of the Congressmen who support the St. Lawrence project.

In the late summer of 1834 a family moved to the region of Bureau Creek (Bureau County, Illinois) from the banks of the Erie and Ohio Canal. The succeeding autumn, a son who had helped construct the canal near the Ohio home, took his gun, and, in his own words, "viewed the country through from Hennepin (on the Illinois River) to the Mississippi River near Rock Island, and thought it was a natural pass for a canal as there was a depression all the way across with high land on either side." This reconnaissance led to a more careful reviewing of the region a few weeks later, the interesting of local influence and the agitation for a waterway to connect the big bend of the Illinois River with the Mississippi near Rock Island. Believing that there might be dollars and cents in it, the Erie Canal having paid for itself in the ten years just past, local interests financed private surveys of the proposed route. The legislature of Illinois was involved in the Illinois and Michigan Canal project, and to this body the matter of extending water transportation to the upper Mississippi was carried. Permission for the building of the canal was given but state aid was not forthcoming, so the matter was dropped.

The growth of population near the junction of the Rock and Mississippi rivers made the need for better communication eastward a more urgent one. The canal project was changed to a railroad, and the line of the C. R. I. & P. railroad was put through almost directly over the first surveyed route for the proposed waterway. Interestingly enough the exorbitant freight rates charged by this railway in carrying cargo eastward, and the example of the influence upon rail rates exerted by the Erie and the Illinois and Michigan canals, again brought about agitation for waterway extension from the Illinois to the upper Mississippi. Private and state aid having been previously sought in vain, in 1863 the project was carried before Congress by Senator Hawley of Iowa, where it became noted in succeeding sessions

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as "Hawley's canal bill". The report of the senate committee to whom the bill was referred illustrates the turn which agitation for water transportation had taken, a turn not at all different from that it is taking in our present Congress. The considering committee said, "No improvement of the same probable cost would be productive of so great a benefit; and that the benefit to be produced would not be confined to the state of Illinois alone, in which the work is situated, but would directly and inevitably embrace the state of Iowa, Wisconsin and Minnesota, and indirectly affect all the states lying west of these, whose railroad lines would bring produce down to be shipped by the canal". How like the current statements we read concerning the St. Lawrence project! Suffice it to say that Congress evidenced sufficient interest to authorize surveys of the proposed route in 1870, 1874, 1882 and in 1886. These surveys having proved the feasibility of the waterway from the engineering standpoint, in answer to the clamor of state legislatures, memorials from waterways conventions, boards of trade and chambers of commerce, in 1890 Congress authorized the construction of the waterway, fifty-six years after agitation for it had commenced and twenty-seven years after the bill had been presented for consideration.

The significance of the twenty-seven years which the Hawley Canal Bill spent in Congress is not remarkable until one considers the changes in the transportation problem that had come about in that time. During this period of agitation railroad growth had been very rapid throughout the cereal region of the upper Mississippi basin. The railroads had become masters of the transportation problem through increase in mileage and through improvement of carriage facilities. This period was one in which railroads set rates unhampered by such governing influences as railroad commissions and without concern for inter-state commerce commissions. The adoption of rates truly in keeping with the service rendered, however, was coming about even at the time when the waterway was authorized in 1890. Had the whims of a slow-to-act Congress, and the political adjustments

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due to party influence which brought about the authorization of the project, encountered the most meager consideration of the evident future of rail transportation, the value of the water-way as a "regulator" in its 1890 environment would have caused it to be held up for even a longer period, if not prevented the expenditure of the more than seven millions of dollars for its construction.

The geography of the region between the Illinois and Mississippi Rivers determined both the general and the specific location of the waterway. The great bend of the Illinois and the eastward bend of the Mississippi near Rock Island invited connection by an artificial waterway. The depression of Bureau Creek led westward from the Illinois at a place where a lake afforded an eastern terminal harbor. Green River led westward from the slope of the morainal divide to the navigable Rock River, whose channel led directly to the Mississippi. The relation of the upper Green River to the flat divide of summit level offered the first suggestion of a to-be-impounded water supply from which the canal could be fed both eastward and westward. Later surveys set forth the feasibility of bringing southward along the flat crest of the divide a canal feeder from the upper course of the Rock River, thus assuring a cheap and satisfactory supply of the water necessary for canal maintenance. The character of the Mississippi between the mouth of the Rock River and the town of Comanche, Iowa, to the northward introduced the problem of finding a suitable western terminus, thus modifying the location of the western half of the waterway. The intervening land mass between the Illinois and the Mississippi did not offer a serious problem in canal construction. The height of the divide necessitated a rise of one hundred ninety-nine feet above river level at low water, an elevation accomplished by twenty-one ordinary locks.

[In passing it is interesting to note that in 1894 lock construction marked the beginning of the use of concrete in canal building.]

The highways of the region introduced a problem of bridge construction and highway embankments; the

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streams of the region necessitated concrete aqueducts through which the canal was carried above them. The earth material encountered was mainly morainal. No rock excavation was necessary except near the upper entrance to the canal around the rapids in the lower Rock River. The position of the C. R. I. & P. railroad necessitated in many cases canal building at a higher level than originally planned, and the circumventing of the rapids near the mouth of the Rock River introduced the use of high embankments to maintain canal level with regard to flood conditions and to slack water. The swampy condition of summit level, a region overlying a former peat bog interspersed with pockets of quicksand, introduced the lining of the canal with planks and clay in order to maintain a channel. The construction of the feeder had as its most serious problem the location of the dam in the Rock River from above which the canal water could be taken. Consideration of the effect upon previous power constructions in the Rock River resulted in the locating of the dam at Sterling, and the carrying of the canal feeder southward along the divide.

Although authorized in 1890, actual construction of the canal did not begin until July, 1892, with the building of the section around the rapids in the Rock River near the town of Milan. This section, four and one-half miles in length, was opened to traffic on April 17, 1895 at a cost of $547,229.93. A dam in the river above the rapids afforded slack water transportation from the eastern end of the Milan section of the canal to Colona, where the main line of the canal joined the Rock River. Water from the Rock River was turned into the feeder in the fall of 1907, and on November 15th of that year, the first vessel passed from the Illinois River through the entire length of the canal to the Mississippi. The actual cost of construction was $7,319,563.39, a figure almost double the early estimates.

"Immediately upon the completion of the canal", said its chief engineer in 1908, "people began to look for the effects its promoters had assured would result from its

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construction. The country through which the canal passes is agricultural and the only large towns on the route located its western terminus. The canal affords a connection with the Illinois River as far up as it is navigable, namely to La Salle. There are many flourishing manufacturing towns on that river or near it, and it is natural to suppose that some of their products—coal, tiles, brick, stone, cement and foundry products,—would form freight for canal carriage. Grain and possibly livestock will be transported by canal. On the west the heavy merchandise of Moline, Rock Island and Davenport may supply some traffic. The effect upon freight rates which was hoped for by canal construction at the time of intense agitation,—eighteen or twenty years before completion—has been realized from other sources than water competition. Rivalry between rail lines, increase of the railroad net, and the effect of larger trainloads and more efficient hauling, had wrought the needed reduction in cost of rail carriage." "The first practical use of the canal", continued the chief engineer, "will probably be to pass launches, house-boats and pleasure craft from the Chicago district and upper Illinois River through to the Rock and Mississippi rivers." The prophecy of the chief engineer has been a true one. The expenditure of almost seven and one-third million dollars in the completion of a seven foot channel between the Illinois and Mississippi in 1907 came even more than eighteen or twenty years too late. Had the waterway been builded immediately after the opening of the Illinois and Michigan Canal in 1848 instead of fifty-nine years later, its extension of navigable water westward would probably have exerted the influence expected. Such a water connection thus established between Lake Michigan and the Mississippi at Rock Island might have saved the discarding of the Illinois and Michigan Canal and have induced authorization of the enlarging of that canal as proposed several times in the days of its decline. Such a waterway might have proved through its usefulness the value of a Lakes-to-the Gulf Deep Waterway to carry water competition southward. Its economic

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history might thus have been one to which the supporters of the St. Lawrence River project might point as evidencing the value of water-way competition in the carrying of the surplus products of a cereal region.

But such is not the story of the Hennepin Canal. Authorized to extend the influence of the Illinois and Michigan Canal westward years after that canal had fallen into decay, authorized to combat the restraining influence of high rail rates when those rates were steadily decreasing, it stands in all of its length of seventy-five miles, its depth of seven feet, its width of eighty feet, its thirty-seven locks with their "ever watchfully, hopefully waiting" keepers, ready for the launches, houseboats and pleasure craft that its chief engineer had prophesied,—a seven and one-third million dollar monument to the persistence of local politicians and their influence upon filling the "pork-barrel" of the Rivers and Harbors Appropriations a little more full. Yet I would not have you think the waterway a useless one. The swampy region of summit level is better drained because the canal receives its tile lines; the health of the adjacent inhabitants is somewhat improved through the bathing facilities afforded by its water section; its piscatorial content attracts the local disciples of Izak Walton; its ice in winter maintains an industry that affords the total return for the capital invested and results in an average annual income of approximately three hundred and fifty dollars; its thirty-seven locks give employment to as many keepers in these days when unemployment is a national concern, and canal maintenance augments that force materially; it staunchly maintains in the minds of its lock-keepers, if not in the minds of the cereal growers along it, visions of crowding craft going eastward, going westward in the day when the Hennepin canal is joined up with the waters of Lake Michigan by a waterway of equal section and the original plan of its conceivers is fulfilled.

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SOME CONTRASTS IN THE GEOGRAPHY OF THE VIRGINIA PIEDMONT AND THE ILLINOIS PLAIN

Bessie L. Ashton, University of Illinois

The Virginia Piedmont and the plain of Illinois represent two decidedly agricultural sections of our country. While they are alike in some respects, the differences are great enough to attract the attention of the most casual observer, the conspicuous contrasts being those of topography and soil and the consequent human response. To one who is accustomed to the monotony of plains such as those of Illinois, the undulating surface of the Piedmont, with its numerous slopes, many of them still wooded, others yellow with grain or green with meadow grass, is truly attractive. To give variety, here and there are great gashes in the covering of vegetation where erosion has gained the mastery, revealing the bright brick-red soil—gaping wounds in the side of Mother Earth. In order to be more exact I have chosen two counties which I believe to be typical of the territory they represent—Prince Edward county of Virginia and Champaign county, Illinois. The comparisons made hereafter refer especially to these two areas.

Prince Edward county, Virginia, lies midway between the Fall Line and the Blue Ridge in the region known as the Piedmont, or, to Virginians, as Middle Virginia. Farmville, the largest town and the county seat, is on the Appomattox river nearly 60 miles from Richmond on the east and about 40 miles from Lynchburg on the west. The southernmost part of the county is in latitude 37°5′—about 180 miles farther south than the southern limits of Champaign county.

While the climate of this section is much like that of Illinois, the geographic position, and to a slight degree, perhaps, the lower altitude, give summers a little hotter, winters not quite so cold, longer spring and autumn seasons, and slightly heavier rainfall distributed somewhat more evenly throughout the year. The high summer temperature, long growing season, and abundant rainfall

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are characteristics which make the climate one of the greatest assets of the State.

Mr. Thomas L. Watson, State Geologist of Virginia, has described the topography of the Piedmont Plateau Province as one "of a more or less smooth, broadly rolling or undulating upland, of moderate elevation, into which the streams have rather deeply sunk their channels. Scattering hills and ridges—unreduced residuals—rise in some cases several hundred feet above the general level of the upland surface of the plateau. Below the upland surface, deep and narrow gorges have been carved by the streams.*" No conspicuous elevation is found in Prince Edward county, its highest point being only 715 feet above the sea, about 200 feet above the upland, and less than 465 feet above the lowest point along the Appomattox river. Higher elevations do occur in the vicinity, however, such as Willis Mt., Buckingham county, which rises to an elevation of 1159 feet, and whose rugged outlines can be seen clearly from Farmville about 12 miles away. It is not only in the greater amount of relief, but in the greater number of streams and slopes that the topography of the Virginia section differs from that of Illinois. The largest square field without a permanent stream that could be laid out in Prince Edward county would contain but little more than 1 square mile, while a similar area in Champaign county would cover at least 18 square miles.

This contrast in topography helps to explain the difference in the use of the land in the two regions. In 1920 less than 32 per cent of Prince Edward county was improved farm land, while Champaign county reported 88½ per cent of the area as such. The reverse is true, however, in woodland in farms, 40 per cent of the area of Prince Edward county and 1½ per cent of Champaign county being given as farm woodland. The response to this difference is in the use of wood for fuel. In this section of Virginia every backyard has its pile of stovewood, and trade in cord-wood is considerable to furnish fuel for the kitchen stove and to feed the small sheet-

* Mineral Resources of Virginia, 1907, pp. 5-6.

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iron air-tight heaters that are in common use there. Such a stove would be a novelty in Champaign county, while a load of cord-wood is seldom seen.

The roads respond to the type of topography found in the Piedmont by clinging persistently to the summits of the upland ridges between the streams, an occasional one following the ridge so continuously as to be known, locally, as "the ridge road". In the rougher sections, as in the vicinity of Willis Mt., where the road must cross the narrow valleys, the frail wooden bridges are frequently carried away by freshets, after which, until the bridges are repaired, travelers cheerfully ford the creeks though they may be 10 to 15 feet wide and offer a drop of from 1 to 2 feet from the road to the stream bed. In order to take advantage of the best grades, the roads are very crooked, many of them requiring a drive of perhaps 17 miles to reach a point 12 miles distant. Some of the roads are hard-surfaced for short distances near the larger towns, but, for the most part, "dirt" roads prevail.

Travel over the roads is done in almost every conceivable way. On Saturday afternoon when the country people are returning from town, one can see people on foot and on horse or mule-back, one and two-horse farm wagons, single and double buggies, automobiles, and even the faithful ox, driven sometimes single, sometimes double, and attached to a farm wagon, two-wheeled cart, or, rarely, to the more aristocratic light buggy. The possessor of the ox is more often colored, that element forming 55 per cent of the population of the county in 1920, but many of the less prosperous whites find in the ox their greatest help. It is easy to contrast with this the many miles of nearly level hard-surfaced road of Champaign county, extending over the country in a straight line for miles and traversed by little but the speedy automobile.

The most conspicuous difference in soil between the Virginia Piedmont and the Illinois plain is one of color. The crystalline gneisses and schists of the former region contain iron-bearing minerals which give rise to a bright brick-red colored soil in the advanced stages of weather-

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ing. Here and there are patches of lighter colored soil which represent the earlier stages of weathering in which disintegration has taken place more than decomposition. These soils are mostly of clay with a compact subsoil which does not allow ready absorption of the run-off during rains, and which results in relatively rapid erosion on even the more gentle slopes such as are not seriously affected in Illinois where made of the looser textured glacial drift. Many years of leaching by the weather, rapid erosion, and continuous cropping of tobacco have impoverished the soil to such an extent that a large use of commercial fertilizer is necessary. On farms reported to the census enumerators in 1920, $147,790 was expended for fertilizer in Prince Edward county as against $33,326 for Champaign county which is nearly three times the size. The contrast in topography and soil between the two regions is further reflected in the valuation of the land, the average land value per acre in 1920 being $25.11 and $339.07 respectively, for Prince Edward and Champaign counties.

In each section agriculture is the predominant industry, 82 per cent of the population of Prince Edward county being rural in 1920, and 52 per cent of Champaign county. Corn is the most important crop in acreage in each case, that cereal occupying 35 and 52 per cent, respectively, of the cultivated land. The more favorable geographic conditions for corn production in the latter county is indicated not only in the larger acreage, but also in the average yield per acre, which is nearly three times as great as in Prince Edward county.* The importance of oats in the corn producing regions where it fits into the labor economy of the farmer is shown in Champaign county, in which it occupies second place in acreage, wheat third, and hay and forage fourth. In the Virginia section hay and forage occupy second place, with tobacco, the great money crop, as third in acreage. Tobacco is also the labor consuming crop, the quality depending not alone on soil and weather conditions, but much on the kind of attention given to it during its growth.

* The proportion is 42:15.

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Topography, soil, labor requirements for crops, and the price of labor are some of the factors affecting the size of farms. It is interesting to note that in Virginia where the rough topography interferes with the most economical use of large machines and where tobacco, which requires a great amount of hand labor, is a leading crop, the farms average less than 100 acres. This is a decrease of 6.2 acres per farm since 1910, probably in response to the recent high price of labor. In Champaign county, where machinery can be used satisfactorily, the farms have an average size of 165 acres, a slight increase over the figures of 1910.

The greatest consequence of the geographic conditions noted is the respective wealth of the two sections. The prosperity of the Illinois plain is an established fact to the Virginian, though the Illinois farmer may not realize his good fortune. The difference is easy to distinguish, however, in either section after a sojourn in the other. The well-tilled, generally level fields of Illinois with a rank growth of crops almost continuous as far as the eye can see, the good straight roads, and the modern and spacious farm buildings present a striking contrast to the wooded or waste slopes interspersed with cultivated fields, some of them offering the prospect of an uncertain yield, the winding roads, and the many small and poor farm buildings of the Virginia Piedmont. In delightfulness of climate, especially the extended spring and autumn seasons, and in beauty of scenery, the Virginia Piedmont far surpasses the Illinois plain, but it does not compare with it in material prosperity.

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COAL RESOURCES OF SOUTHERN ILLINOIS COUNTIES JUST NORTH OF THE OZARK OUTLIER

W. G. LATHROP, JOHNSTON CITY

The Illinois coal field is a spoon-shaped basin with the Duquoin anticline at the west edge, the LaSalle anticline at the east edge, and the Ozark uplift at the south. From the foothills of the Ozarks and from the Duquoin anticline where the beds appear at the surface, the coal seams deepen to the east and north at the rate of from forty to sixty feet per mile, reaching their maximum depth of 1200 feet in White County or vicinity. It is the coal resources of the southern counties of this basin that I desire to discuss in this paper.

The coal beds of the state are all found in the Pennsylvania series of the carboniferous system and are numbered from one to seven upward from the bottom. The producing beds included in this discussion are number two, or Murphysboro, number five, or Harrisburg, and number six or Herrin. Seam number six, known as the "blueband" coal, is the greatest single producing seam in the state, having an average thickness of nine feet, five inches. Coal number five lies about twenty-five feet below the number six, and has an average thickness of four and one-third feet. Vein number two varies in thickness from one to six feet.[1]

COMPARATIVE PRODUCTION

The bituminous coal field of Illinois underlies three-fourths of the state. Eighty-five counties share in the wealth of this, the greatest of bituminous fields. It was estimated by the State Geological Survey in 1907 that the original deposits in Illinois amounted to 136,966,000,000 tons. At that time the Survey estimated that 645,868,309 tons had been mined. Based upon an average of 62% recovery in mining, there had been mined and wasted in 1907 about 891,000,000 tons.[2] Since 1907 there have been mined and wasted 677,747,615 tons of coal in Illinois fields.[3] This gives a total of 2,205,858,000 tons of coal

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mined and wasted (based upon 62% recovery) in Illinois up to 1919. This is a little over 1.6% of our original deposits, leaving a reserve of nearly 135,000,000,000 tons at the beginning of 1919.

In 1918 Illinois produced 89,291,105 tons of coal, more than 15.4% of the total bituminous production of the United States for this year.

The leading counties entering into production in this part of the state, in order of production, are Franklin, Williamson, Saline, Perry, and Jackson. In 1918 Franklin produced 12,373,356 tons, valued at $29,224,580. This was almost 14% of all the coal mined in the state for that year. In the same year Champaign County, our greatest corn producer, produced corn valued at $13,869,931, not quite half the value of the Franklin County Coal.[5]

Franklin and Williamson, our first and second coal counties, produced in 1918, 23,711,918 tons of coal (valued at $55,363,559), over 26½% of the state production for this year. The five counties named above hoisted in 1918, 33,369,327 tons, 37.37% of the total hoist for the state. The value of this coal was $77,992,252, and may be compared with the value of the corn produced by our five leading corn counties (Champaign, Fulton, McLean, Pike, and McDonough) for the same year. The value of the corn is $60,632,678, the coal leading by more than $17,000,000.

MINING

The coal of these five counties is produced by 181 mines, including 54 local mines, 17½% of all the mines of the state, employing 36,736 men, 38.3% of the miners of the state who in 1918 averaged over 1307 tons of coal per man. Practically all the coal is mined from shaft mines, though strip and slope mines are common near Marion and Carterville on the south, and Duquoin on the west where the Ozark foothills and the Duquoin anticline bring the coal-bearing strata near the surface. Many acres at the south edge of the basin have had the coal removed by the strip mine method. Near Carterville, it is reported that by modern steam shovel methods it is profitable to remove as much as 30 feet overburden.

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Stripping unfits the land for any agricultural purposes except pasturing. The surface is left in a very uneven condition and erosion attacks it readily.

MARKETS

Illinois consumes more than 50% of her own production of coal. Chicago consumes about 14%, and St. Louis and East St. Louis use about 10%. Because of competition of eastern coals, practically no Illinois coal goes eastward, although some has reached northeastern markets in recent years. No coal goes south, and the region north of the lakes is supplied by the lake traffic with eastern coal. Our best outside markets are to the northwest, to the Minneapolis and St. Paul region. Competition between Illinois coals and those of eastern states favors the outside coals because of the better quality of the coal, cheaper labor and cheaper transportation where this is done by streams and lakes.

EFFICIENCY AND CONSERVATION

More than 98% of our vast coal resources is still beneath the surface. Using the production of 1918 as a basis, and calculating on a recovery of 50%, which I believe to be more nearly correct, there are being mined and wasted about 175,000,000 tons of Illinois coal per year. There is no evidence that the rate of removal will not increase for some years to come. On the 1918 basis of removal, the coal deposits of Illinois will be exhausted in 800 years. Operators near Johnston City and Herrin think this part of the field will be active for a period of 50 years from the present date. Of course other areas less accessible will come into prominence as the more favorably located deposits are exhausted. But is 50 years a sufficient look into the future? Is 800 years to be considered as the limit of time during which we should expect to use coal? Should we not begin now to consider more efficient uses of our coal supply in order that its life may be lengthened?

In order to do this we should begin at once to get at the root of the evils. Wastes due to mining operations,

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such as mining lower veins first and leaving 50% of the coal underground, should be given up. Practice of better uses of coal should be encouraged. Smoking chimneys which waste millions of tons of coal annually should be eliminated. Engines securing a higher efficiency from coal fired should be put into use. The mechanical stoker has aided greatly in correcting the last mentioned evil. The Central Illinois Public Service Company, whose plant is located at Harrisburg, Illinois, reports through Supt. Cook of Marion, Illinois, that with stoker firing and tubular boilers, it is possible to get a kilowatt hour of electricity from each 2.75 lbs. of coal fired. The hand firing process requires 4.75 lbs. This is a saving of about 42% of coal formerly used by this company.

The Illinois Tractions system, also, reports that with the Curtis and Parson turbines and with Corliss engine generators they are able to get equally good results. But the average for this company is 5.5 lbs. per kilowatt hour, on an average production of 543,450 kilowatts per day. This shows that a vast saving can be effected through the use of better machinery.

Mr. Hight, chief engineer for the Illinois Traction System, says, "The most efficient means of decreasing coal consumption is by learning more completely how the coal may be fired. A greater knowledge of the use of coal and the method of firing it and handling it will be most important steps toward efficient use of coal and a greater saving and lower consumption of it."

Coking of the coal and the substitution of gas engines for steam engines mean a great extension of the life of our coal deposits. As late as 1917 Illinois coal was classed as non-coking coal of high sulphur content. It was also mentioned that investigations along the lines of coking Illinois coals were at that time preliminary and that even small improvements might be expected at any time which would revolutionize our uses of bituminous coal[6].

These words read almost like prophecy, for at this time, only five years later, 100% Illinois coals and mixtures of high percentage of Illinois coals are being coked successfully. Plants at Duquoin and Centralia, while

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small, are using 100% No. 2 coal. These companies get 1200 lbs. of coke and 10,000 cu. ft. of gas per ton of coal coked.

The St. Louis Coke and Chemical Co. at Granite City are coking a mixture of 90% No. 6 coal and 10% Pocahontas. This Company uses the Roberts type of coke oven, mentioned so favorably in the Iron age for March 2 and 9, 1922. They coke 1400 tons of coal per day with a recovery of 68.14% of the coal charged. As by-products they obtain 10,840 cu. ft. of gas, 9 gallons of tar, 27 lbs. of ammonium sulphate, and 3½ gallons of light oil per ton of coal. This company gets only 25c per thousand for its gas, while the gas companies at Duquoin and Centralia get $1.85 per thousand. The coke brings $7.50 per ton, a little more than the coke of the other cities mentioned. Coke is the equivalent of the same number of pounds of anthracite. It is cleaner and more economical than raw coal. That produced at Granite City is used for zinc and lead smelting, blast furnaces, water gas, and household purposes.

Mr. Farrar, of the Southern Illinois Gas Company at Murphysboro, thinks most of the gas plants of the state would use Illinois coal immediately if the State Utility Commission would reduce the standard from 565 B. T. U. to 500 B. T. U. per cubic foot, since with straight Illinois coal it is difficult to get a gas of the required standard. The gas companies, he thinks, would then create a market for their gas-house coke through the education of the people to its advantages.

This seems to be the road to true efficiency and conservation. The coal should be coked near the mines, and can be sold for use in bakeries, smelting, blast furnaces, household uses, and perhaps for firing railroal engines.[7] The gas produced can be sold to surrounding cities for fuel, and used on the spot in gas engines to generate electricity, for light and power. Electric energy may also be used to transport the coke to places of consumption through the use of the electrified railway, since transmission is now possible over a distance of 500 miles with slight loss. The Illinois Traction System reports a line 450 miles long in operation. Coking by means of the

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by-products oven also makes available for utilization vast quantities of by-products.

I have tried in this small way to discuss a slight portion of the most important resource which nature has left us. It is ours to use, not to abuse; to consume, not waste. Let us accept it as our treasure, use it as our friend and ally, and in turn pass it on to those who are to follow us with as little impairment as possible.

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POSSIBLE HORIZONS FOR OIL AND GAS IN NORTHEASTERN ILLINOIS

U. S. GRANT, NORTHWESTERN UNIVERSITY

During the last twenty months an interest in drilling for oil and gas has developed in several places in the northeastern part of the state. Companies have been organized, leases have been taken, and some actual drilling has been done. The greatest interest has been near the northern edge of Cook County, the southern edge of Lake County, and in western McHenry County. It consequently seems proper on this occasion to outline briefly the horizons in which there is a possibility of the occurrence of oil or gas. Beginning with the latest formations, these horizons may be listed as follows:

1. *Glacial Drift.* Lying below the most recent or Wisconsin drift there is frequently an old soil zone or a zone containing large amounts of vegetable material, especially remains of trees. Probably more than one such horizon is present in some localities. Wells have been sunk to one of these zones rich in organic matter, and gas has been obtained from a great many such wells. The gas pressure at first is occasionally quite strong, but usually soon declines so that it is only a few pounds per square inch and eventually this pressure may disappear altogether. However, in a number of places such gas wells have furnished and undoubtedly will continue to furnish for years to come local supplies which can be used in farm houses or possibly in small communities. Showings of oil in these same horizons have also been reported.

2. *Devonian Shales.* In a few places in the eastern part of the state, either in cracks in the Niagara limestone or in small masses probably detached in the drift, remains of Devonian black shale occur. This shale is frequently highly carbonaceous and might form a source for oil or gas, but the lack of any extensive bodies of this material under a suitable non-porous cover makes it im-

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probable that oil and gas will be obtained from this horizon.

3. *Niagara Limestone.* In a number of localities small asphaltic residues have been found in the more porous parts of the Niagara limestone, especially near its top, and in certain places wells have encountered considerable pockets of gas and sometimes a little oil in the bottom of the drift and in the top of this limestone. In places the oil is sufficient in amount to spoil water wells, but has not been found in sufficient quantity for economic use. Early reports of borings in the Niagara limestone state that a few barrels of oil were obtained from that formation. Locally a thin sandstone may occur at the base of the Niagara, and this is a possible oil and gas horizon.

4. *Maquoketa Shale.* While this formation is composed largely of clayey shales passing into impure limestones, in a few horizons small carbonaceous layers have been reported, and a few well borings have reported some oil showings in these shales.

5. *Galena Dolomite.* This heavy dolomitic formation underlies the northeastern portion of the state and has been penetrated by many wells. Only a few very meagre oil showings have been reported from this horizon. However, in the northwestern part of the state, i. e., in the upper Mississippi Valley lead and zinc district, at the very base of the Galena dolomite is a peculiar chocolate-colored shale known locally as the "oil rock". This is very rich in carbonaceous material,—in fact from it oil and gas can be distilled and dry splinters of the shale burn with a smoky flame. This peculiar carbonaceous shale is confined mainly to the lead and zinc district and exists, if at all, only in small quantities in the northeastern part of the state. There is still a possibility, but not a probability, that thicknesses of this material sufficient to furnish small supplies of oil and gas may be found in that part of the state.

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6. *Platteville Limestone.* The upper part of this formation in the northwestern part of the state also sometimes contains very thin seams of the oil rock, while the lower part of the formation is dolomitic and more porous. Rocks of this same age have furnished large quantities of oil and gas in both Indiana and Ohio, but not in Illinois.

Geological Structure. The northeastern part of the state consists of a low monocline dipping very gently to the east or a little south of east, and is the eastern limb of the main structural axis of the state, i. e., the LaSalle anticline. Local irregularities may, and probably do, occur in this monocline, but in order to furnish proper structures for the accumulation of oil and gas there should be well defined domes. While such structures may possibly exist, they have not yet been found and their locations, if they do occur, would be attended with much difficulty and uncertainty because of the heavy covering of drift in most of the district. Sandstone lenses would also be very difficult to locate.

Well borings. Mention has already been made of a number of shallow wells which have obtained gas from the glacial drift or from the upper part of the Niagara limestone. Large numbers of deep borings for artesian water both to the St. Peter sandstone and the Potsdam sandstone,—the two main aquifiers of the district,—have been made. Many of these wells have penetrated one or more of the horizons noted above, and most of these wells furnish fresh water of good quality, while a few are somewhat charged with salts, but none have found the decidedly briny waters which are so commonly associated with oil and gas.

SUMMARY

Summing up the above, it may be said that small local supplies of gas can be looked for in the drift and in the upper part of, and perhaps at the base of, the Niagara limestone, but the chances of finding large amounts of either oil or gas in these horizons are not encouraging.

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While possibly structures favorable to the accumulation of oil and gas may be found in the northeastern part of the state, the chances of locating such structures are small and there is no convincing evidence that such structures, if located, would carry considerable quantities of either oil or gas. Thus the district as a whole offers very little encouragement to prospecting for oil and gas, and the chances for success in such prospecting are very small, while the chances for failure are very large.

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MAN AND TOPOGRAPHY IN SOUTHWESTERN WISCONSIN

W. O. Blanchard, University of Illinois

The topography of southwestern Wisconsin, south of the Wisconsin River and west of the glaciated section, is in marked contrast to that farther east. The first is characterized by a rough, maturely dissected surface with precipitous slopes and castellated rocks; the second by gently rolling topography with the rounded hills, gentle slopes and shallow valleys typical of a recently glaciated region.

Within the district itself the degree of dissection is not uniform. Roughly parallel to, and about 10 to 12 miles south of the Wisconsin River is the Military Ridge. It represents the crest of the Galena Trenton cuesta. The escarpment slope of the cuesta drops off rapidly from the Ridge to the flood plain of the Wisconsin River 500 feet below. On the opposite side the back slope dips gently southward to the Wisconsin-Illinois state line about 35 miles away. This latter slope is about one-fourth the former and the dissection of the surface is, therefore, correspondingly less.

Of the various geographical factors which have operated to differentiate man's activities in this region as a whole from those in the region to the east, as well as those on the escarpment from those on the back slope, topography has by all odds been the most important. Differences of climate, position and resources are negligible in comparison with those of relief.

The handicap of a maturely dissected terrain is felt directly or indirectly by all the inhabitants and in all occupations. Along two lines—communications and agricultural activities—the influence is most marked. Some of these are indicated below.

Because of the geographical location of southwestern Wisconsin on an air line between the great transportation centers of Chicago and the Twin Cities, one would expect it to be on the line of the great transcontinental

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route. However, the topography of the region repels rather than invites the great trunk routes, and they bend to avoid it, leaving this section an island in the stream of traffic which sweeps by on either side. As a result the railroad service here is typical of branch lines—second rate rolling stock and limited accommodations in general.

In the matter of highways, rough topography has placed a heavy burden in the cost of construction, operation and maintenance as compared with the glaciated counties immediately to the east.* By selecting items of construction which bear intimate relations to topography such as the cost of (1) surveying, (2) grading, (3) bridges and culverts, and (4) guard rail, some idea may be gained of how real an expense these communities are put to in road construction. For the items named the difference in cost of construction of the state aid highways from 1914-1917 inclusive averages $1,531.73 per mile of road greater than in the level counties to the east. This is added cost due, not to greater expense in unit cost of materials, but to greater mileage of guard rail, more bridges, more grading and greater difficulty in surveying. The total additional cost for these 4 items for the state aid roads built during this period was almost $25,000 for three counties.

The absence of gravel in this region, so common as mounds and ridges in glaciated sections, has resulted in a large proportion of the roads remaining unsurfaced. Of the state aid road constructed in this region from 1912-1917 (202 miles) about 1/3 (35%) was hard surfaced. The glaciated counties built in the same period twice the mileage and hard surfaced over 9/10 of the total.**

Important as is this excessive initial cost, it is, of course, in the time and energy required to transport goods over such inferior roads as well as in the high cost

* Grant, Iowa, and Lafayette counties in southwestern Wisconsin are compared with Rock, Columbia and Jefferson counties, the nearest counties on the east wholly glaciated.

** Wisconsin Highway Commission Reports.

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of maintenance that the burden bears most heavily. And it must be remembered that this region is almost entirely agricultural where commodities to be moved are heavy and comparatively cheap.

Let us now turn to the effect of topography upon the utilization of the land. Conspicuous examples illustrating their intimate relationship may be found within the region itself in contrasting conditions upon the escarpment and back slope of the cuesta.

Thus we find that the back slope in proportion to its size had, because of its more favorable relief, 50% more of its total land classed as improved. While the average farm was smaller by 37.5 acres, its value, equipped, was about 75% greater and the farmer's income was estimated at about 1/3 more than on the escarpment. Chiefly because of its more favorable topography specialization* in corn was 21% higher on the back slope, and since corn growing is usually associated with swine and butter production, specialization in these two ran 200% and 100% higher respectively. The dairy speciality of the escarpment, on the other hand, with its relative scarcity in corn and hogs, turns to cheese, in which its specialization ran 30% higher.

And finally, because of its greater agricultural productivity, we have, on the back slope, better social and economic conditions being maintained in a population twice as dense as on the rougher escarpment.

* The degree of specialization is obtained by taking the square root of the production per capita and production per acre of improved land." B. H. Hibbard.

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FOSSIL FLORA OF BRAIDWOOD, ILLINOIS

A. C. Noé, University of Chicago

Braidwood is situated fifty-nine miles southeast of Chicago on the Chicago and Alton Railroad. Two miles northeast of the Chicago and Alton Station is located a medium sized coal mine which was still working before the beginning of the strike, and which it is to be hoped will continue to be active for a long time to come after the strike is settled. It is the last coal mine in Mining District No. 1 (Longwall) which contains large numbers of excellent plant impressions. The owners, the Skinner brothers, are very friendly toward collectors, and the active member of the firm, Mr. David Skinner, together with his mine manager, Mr. William Oswald, cordially welcome and generously treat all serious-minded collectors of fossil plants who visit their mine. They receive every year several times, large and small geology classes from the University of Chicago, and give them every facility for studying their mine and their fossils. The author takes great pleasure in acknowledging his indebtedness to these two men.

The log of Skinner mine No. 2, the mine in question, is lost, but the log of the Maltby mine, located in the next section east, and abandoned in 1887, is still at hand. According to it, the workable coal seam begins at a depth of 48 ft., 4 in. This seam is 40 inches thick, with 20 inches of fire clay below it. Under this fire clay lies another coal seam 9 inches in thickness, and under it are 18 in. of fire clay. Above the workable coal seam is a layer of shale of a thickness of 25 ft., 4 in., above which follow 8 ft. of sandstone, 8 ft. of blue clay, 6 ft. of gravel, and 1 ft. of soil. The fossil plants occur in a zone of about 6 ft. in the shale, beginning immediately above the workable coal seam. They are most numerous next to the coal. The fossils appear in either calcareous concretions embedded in the shale, or as impressions directly in the shale.

The shale of Braidwood consists of various species of Calamites, Annularia, especially A. Sphenophylloides,

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Lepidodendron, Sigillaria, Ulodendron, Stigmaria, Sphenophyllum, especially S. marginatum, Pecopteris, especially P. unita and P. villosa, Alethopteris, especially A. lonchitica, Callipteris, especially C. Sullivanti, Neuorpteris, especially hirsuta, and various types of Sphenopteris, Odontopteris, and Palmatopteris. Also various seeds of Cycodofilicales, like Trigonocarpus, and leaves of Cordaites are frequent.

The flora of Braidwood resembles closely the famous deposits of the Mazon Creek and Coal City, which are situated in the neighborhood. It is different from that of Colchester and Murphysboro, Ill., which also belong to horizons similar to those of Braidwood.

If we compare the Braidwood flora with the standard deposits of Pennsylvania and of Europe, we come to the conclusion that it corresponds to the lower Alleghany formation of Pennsylvania (Kitanning), and to the upper Westphalien and lower Stephanian of western Europe. The horizon of Mazon Creek was usually considered as lying at the basis of the Carbondale section of the Pennsylvania formation of Illinois immediately above coal No. 2.

Since lately the correlation of Illinoisian coal seams has become questioned, it may be wise to postpone a definite stratigraphic assignment of the Braidwood flora until the time when the horizons of the coal measures of Illinois are again definitely fixed.

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NOTES ON THE WATERLOO ANTICLINE

J. Everts Lamar, State Geological Survey, Urbana

The Waterloo anticline is located between the towns of Columbia and Waterloo, in Monroe County, Illinois, about 28 miles southeast of St. Louis. The structure was first worked out by Dr. Stuart Weller in connection with his geologic mapping of Monroe County for the Illinois State Geological Survey. In the fall of 1920 a heavy oil was encountered in the Kimmswick limestone in a well drilled for water by the Waterloo Condensed Milk Company. Shortly afterwards two press bulletins were issued by the State Geological Survey, the first by Mr. H. E. Culver, and the second by Mr. L. A. Mylius, in which the structure was delineated and recommendations made for drilling. This is the most recent case where the Survey has called attention to favorable field conditions and directed successful exploration.

Up to the present time there have been 55 wells drilled on the anticline, and of this number 33 are producers, 12 dry with a showing, 3 incomplete, and 7 dry. Wells with good locations on structure come in at from 75 to 125 barrels, but soon drop off to 25 or 50 barrels per day. They do, however, make good consistent pumpers, and because of the nature of the pay are likely to be long lived.

THE STRUCTURE OF THE WATERLOO ANTICLINE

The structure is that of a long, narrow, sharp crested asymmetrical anticline, extending approximately from north to south, with its maximum width of about one mile near the north end, and tapering abruptly to the north, but extending as a long, narrow fold for about 3½ miles to the south. The total length of the anticline is about five miles.

The west flank is by far the steeper side with an average dip, as indicated by structure contours on the Kimmswick limestone, of about 10° to the west. In the vicinity of the producing area it is cut by a normal fault with its upthrow side to the east, which probably dies out into a monocline to the south. This fault brings inclined

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Warsaw beds in contact with almost horizontal Chester beds. Its presence is further substantiated by a well drilled apparently on the fault plane or close to it, which encountered considerable "creviced rock" and clear transparent quartz, as well as a rather unusual succession of limestones.

The east side of the anticline is much less steep than the west, and has an average dip, as indicated by structure maps, of about 4° to the east.

THE PRODUCTIVE AREAS

The greater part of the production in this field comes from a tract about a mile long and a third of a mile wide, which comprises the top of the anticline. Most of this area has already been drilled, but there is a possibility of the extension of production somewhat farther to the north and south, particularly along the axis of the anticline.

There has been a little production about three miles south of the main pool in section 24 on what appears to be a narrow terrace, or slight flattening of the pitch of the main anticline. The wells located on the top of this terrace come in at from 5 to 10 barrels, and those slightly off on the sides, though dry in the Kimmswick, show gas in small quantities in what is probably the Keokuk-Burlington.

Between the large and small producing areas and also south of the latter, all wells drilled on the axis of the anticline have showed oil, but none in sufficient quantities to make profitable wells.

THE GEOLOGIC COLUMN

The geologic column in this area is relatively simple, but some interesting features are brought out in studies of the well cuttings. The formations may be described briefly as follows:

THE MISSISSIPPIAN SYSTEM

St. Louis Limestone:

The St. Louis limestone is a fine grained, dense, hard, compact rock which locally contains numerous nodules

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of chert. It is entirely eroded from the top of the anticline and is exposed well down on the flanks. The maximum thickness shown in well records is 185 feet.

Salem Limestone:

The Salem limestone, like the overlying St. Louis, is also eroded from the top of the anticline. Where exposed, it consists of a fine and coarse grained, moderately hard, gray-white and speckled limestone. Locally it contains chert, and is commonly oolitic. As noted from well records its thickness varies up to 140 feet.

Warsaw Limestone and Shale:

The Warsaw outcrops on the flanks of the anticline, but it is entirely eroded from the crest. It consists of gray and buff, crystalline limestone, moderately hard, and locally argillaceous, and interbedded with thin layers of shale. In the upper beds of the formation *Spirifer washingtonensis* and *Productus magnus* are abundant. Its thickness ranges up to 125 feet.

Keokuk-Burlington Limestone:

The Keokuk-Burlington is the oldest formation exposed on the anticline. It consists of coarsely crystalline, or granular, white limestone with much interbedded blue-white chert. Its thickness varies from a few feet on the top of the anticline to about 240 feet well down on the flanks.

Kinderhook Limestone and Shale:

The Kinderhook formation has two phases, the upper shaly phase and the lower limy phase. The upper phase is not every where present; in fact it is more commonly absent than present, and so far as known does not outcrop in the vicinity of the anticline. It appears more commonly in the logs of wells drilled near or on the axis of the anticline, and has a thickness of from 32 to 110 feet, with an average of 70 feet for the eight wells in which it is logged.

As indicated by the disparity between the maximum and minimum thicknesses, the shaly portion of the Kin-

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derhook is largely eroded and the declivities of the eroded surfaces are apparently abrupt and sharp since a horizontal distance of a few hundred feet may make differences of 60 or more feet in the thickness of the shale or may even account for its entire disappearance.

The lower phase, the Fern Glen limestone, averages about 30 feet in thickness, but with extremes as low as 11 and as high as 60 feet. The limestone is coarse grained and of variegated shades of brown-red, dull red-purple, pink, green, and white. The red and purple limestones have a dull, dead lustre, while the remaining pink, green, and white have the vitreous lustre of crystalline calcite. The red color of the limestone is probably due to minute particles of red ferruginous shale and hematite. Locally the Fern Glen contains chert, crystalline calcite, and commonly the top or medial portions contain thin beds of red, gray, or greenish-gray shale. Where the formation is thick, however, it is roughly divisible into the upper and lower red limestone beds, with intermediate beds of gray or green shale.

In the vicinity of the anticline, the drillers estimate the interval between the top of the Fern Glen and the top of the Kimmswick as 200 feet. As a rule this applies to the interval between the top of the "red rock" and the first showing of oil below the "black shale". Logs bear this out, and in almost every case the interval between the two horizons mentioned is from 200 to 220 feet. This is rather surprising when it is remembered that the Devonian in this area is unconformable above and below, and varies from a few feet up to 75 feet in thickness, and that the Trenton cap, the Fernvale, also is not of constant thickness.

THE DEVONIAN SYSTEM

Judging from the number of logs which do not record the Devonian limestone, it is not every where present. Whether it has been logged with the Fern Glen or really is absent can not be stated definitely. However, in the 20 logs in which it is recorded, it has a range in thickness of from 20 to 75 feet and averages 40 feet.

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The limestone is gray-white, coarse grained, and moderately hard, and is unconformable with the beds above and below.

THE ORDOVICIAN SYSTEM

Maquoketa shale:

The Maquoketa is a dense, dark gray shale. Its thickness, as indicated from well logs, averages about 85 feet on the top of the anticline. Well down on the flanks of the anticline its thickness is as great as 145 feet.

Fernvale limestone or "Trenton Cap":

Figures on the thickness of the Fernvale are very difficult to obtain, primarily because it is followed below by a limestone, with which it is commonly included by the drillers. This is not surprising because locally the top of the Kimmswick "tightens up" so as to be difficult to distinguish from the Fernvale without careful examination. However, from the best available information, the average thickness of the Fernvale may be considered about 12 feet. The minimum thickness noted is 2 feet, in the log of a well drilled approximately on the axis of the anticline, and the maximum thickness of 29 feet, somewhat off on the east side of the anticline. The Fernvale is a dense, fine grained, hard, brittle, thin bedded, white limestone.

Kimmswick limestone ("Trenton"):

The Kimmswick is a coarse grained, moderately porous, coarsely crystalline, white limestone, and tests above 95 per cent calcium carbonate. When bailed out from a well it resembles very closely a true sand, and is so called by the drillers. Particularly is this so when the limestone does not contain oil, and is therefore pure white. The coarsely crystalline character and porosity make the Kimmswick a good oil reservoir, though locally it is rather "tight", particularly in its upper portion, and well down on the sides of the anticline. The top of the Kimmswick is irregular and unconformable with the formation above.

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THE WELLS

In general, the wells in this area are drilled to a depth of between 475 and 550 feet, depending on the elevation of the curb of the well. The greatest difficulty in drilling is encountered in going through the cherty Keokuk-Burlington, and in some cases through the Moquoketa, which breaks up easily but will not mix with the water in the hole and is therefore difficult to drill through. At the present time wells are put down in from a week to 10 days, barring delays due to the failure of the drilling machinery. The general procedure is to drill the wells until the sand begins to show the first indications of water. On the crest of the anticline this means a drilling of about 50 feet into the Trenton before water is struck, while in producing wells off the axis water is usually encountered at about 30 feet. There are apparently no formations which are consistent aquifers in any one particular horizon. Parts of the Warsaw and Keokuk-Burlington, however, are reported by drillers to be creviced, and from such portions of these formations there is the greatest influx of water into the hole above the Maquoketa.

THE SOURCE OF THE OIL

In all probability the thick Trenton limestone and the Maquoketa shale are the formations in this area from which the oil has come. It is not an uncommon thing to encounter a strong odor of oil or even a little black oil in drilling through the Maquoketa shale. While this fact in no way proves that the Maquoketa was one of the sources of the oil in the Kimmswick it at least indicates that the Maquoketa may well have furnished some of the oil now found in the Kimmswick.

The oil which has accumulated in the Waterloo anticline probably migrated largely from the east and southeast. The Valmeyer anticline shuts off migration from the south and southwest, a syncline between the Waterloo anticline and the Mississippi River bluffs excludes extensive migration from the west, and to the north other smaller folds probably have acted as barriers preventing marked migration from that direction.

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THE OIL

The oil secured in the Waterloo field is about 28° Beaumé gravity, with a high coke residue. After this residue is removed, however, the remaining oil gives a very high yield of the lighter distillates. It is black oil and contains a relatively small amount of gas and sulphur. The oil is steamed and then run into tank cars in which it is transported to the oil refineries at Wood River. The production at the present time is about three tank cars per day, and the selling price of the oil is $1.75 per barrel.

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DESCRIPTION OF A BOULDER NEAR THE SOUTHERN LIMIT OF GLACIATION IN ILLINOIS

CLARENCE BONNELL, TOWNSHIP HIGH SCHOOL, HARRISBURG, ILL.

The boulder to be described is of significance only on account of its size and of its location near the southern limit of glaciation in America. The published maps of the glaciated areas show "farthest south" in glacial movements to be in Saline county on a line curving southward to follow approximately the east and west trend of the Saline river, which in turn follows rather closely the northern base of the Ozark hills.

It should be noted that boulders are not a prominent feature of the southern Illinois drift as they are north of the Shelbyville moraine in the later deposits. The earlier geologists mention granite boulders in Saline county as large as the two fists, but I have not been able to find specimens during a residence of eighteen years. It has been necessary to import a few from the old home farm in central Illinois for class room demonstrations.

Reports from students, of what was supposed in their neighborhood to be a "meteorite" lying in a field just southeast of the village of Carrier Mills, led me to this boulder. It lies on a low ridge in a cultivated field owned by Mr. Marshall Thompson who lives on the place. The exact location is near the middle of the south line of the SW¼ of the NE¼ of Sec. 2 Twp. 10 South, Range 10 East of the 3d Principal Meridian. About ten years ago, Mr. Thompson, while plowing deeper than usual, scraped the top of the stone which was covered with earth. Curiosity led him to uncover it and, later, to dig under and set two sticks of dynamite with which he raised it to the surface, or nearly so, at the same time breaking it into three pieces. It differed so much from the ordinary stratified rock fragments which are more or less abundant in the county that the "meteoric" theory of its origin arose. In fact, people were found who "had seen it fall" sometime in the dim past. Mr. Thompson has

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the smallest of the three fragments in his yard. I have samples from this smaller one and pictures of the two larger ones which now lie partly out of the ground.

The part of the field where the boulder lies is slightly higher than the part to the north. Also, the ground slopes gently to both the east and west and more abruptly to the south toward the edge of what was once a great cypress swamp extending two miles farther south to the Saline river. It is but a few hundred yards to the edge of the swamp. Beyond the Saline, the foothills of the Ozarks begin within a mile or two, and the altitude increases rapidly within the next two miles. There seems to be no possibility that the ice sheet could have extended more than four or five miles to the south of this boulder; and I have found nothing in the nature of the soil or topography to indicate that it even went beyond the present location of this rock, though it could have done so as has been indicated. That is, it could have gone four or five miles farther at this particular point without the necessity of climbing the mountain to the south.

The surface soil about the boulder is described by Mr. J. E. Whitchurch, Saline County Farm Advisor, as a yellow or yellowish-gray silt loam such as is common to much of the hill land of the county. Mr. Thompson says that the soil immediately surrounding the rock at the very top of this low ridge will raise more kinds of crops than will the soil on the slopes but a few feet lower down. This lower slope soil which evidently underlies that at the crest is very acid and is described as a deep gray silt loam. The same kind of soil outcrops along the roadway and ditches to the northeast of Mr. Thompson's farm. Mr. Thompson says that a well dug and drilled about 200 feet south of the boulder came to the No. 5 coal at a depth of about 45 feet. He thinks that shale and sandstone would be found at about 20 feet below the boulder, basing his estimate on their known depth at other places near. The elevation above sea level is approximately 380 feet.

The stone is a light red granite. Careful estimates of the size, made after some excavating, and of the density

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of small fragments, give 4,725 pounds as the approximate weight of the three fragments. There are no evidences of striation or other glacial marks.

The size, position, and elevation of the boulder are such that there is no possibility of its having been transported from its original bed except by natural forces. It should be of interest on account of its nearness to the southern limit of glaciation in America. There is strong probability that it may remain as a monument marking the point of the most southern migration of its kind.

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PLEISTOCENE MOLLUSCA FROM THE VICINITY OF JOLIET, ILLINOIS.*

FRANK COLLINS BAKER, CURATOR, MUSEUM OF NATURAL HISTORY, UNIVERSITY OF ILLINOIS

Several collections of Pleistocene fossil mollusks from the vicinity of Joliet have recently been submitted for study, which are of unusual interest from the standpoint of geological and geographical distribution. All of the deposits are Post-Glacial in age and represent several stages in the history of Glacial Lake Chicago. It is, of course, difficult or impossible to exactly correlate these deposits with the lake stages, but the contained life indicates that the lake was populated from the Desplaines and Illinois valleys.

MATERIAL FROM THE FAIR GROUND QUARRY, JOLIET

This material was collected by Mr. James H. Ferriss, of the Joliet Daily News, a veteran collector of mollusks, both recent and fossil, and represents several years work. It is thus as complete a collection as could well be made and probably includes about all of the species possible to be found in these strata. Fifty-six species are included, of which eight are bivalves, six water breathing gastropods, 19 pulmonate aquatic gastropods, and 23 land gastropods, altogether forming one of the largest aggregations of Pleistocene Mollusca from one place. One variety is recorded as new, a species listed from Pleistocene deposits for the first time, and the distribution of several recently described species and varieties is enlarged.

Mr. Ferriss thus describes the stratigraphy of the deposits at this locality:

"Above the limestone on the east side, about the center of the prehistoric pond, the marl is nearly pure and of a thickness of from six to ten feet. Then is found a bed of peat with stumps and cones of Arbor Vitae and White Cedar, which do not grow within many miles of

* Contribution from Museum of Natural History, University of Illinois, No. 26.

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Joliet. Marl and sand and clay adulterate the peat in certain layers, while in others it is almost pure peat. The material above the limestone measures in all upwards of 20 feet in thickness and contains shells all the way through, the water shells largely in the lower levels and the land shells in the upper strata."

The lower strata containing the marl probably represent a stage when the valley was largely filled with water from the Chicago outlet and there was little territory for land mollusks to occupy. Later, when the outlet became reduced to a narrower river, or perhaps during some of the low water intervals between the different lake levels, land mollusks came and took possession of territory above the river. It is probable that the lower strata which contain such an abundance of fresh water mollusks represent the earlier stages of Glacial Lake Chicago, perhaps as early as the Calumet or even following the Glenwood, for many hardy mollusks, such as many of the species represented are, probably followed the ice very closely, and there is no reason why the water at Joliet, 30 or 40 miles away from the ice, could not have supported some kind of a snail fauna. A huge boulder overlying a bed of Unios in the bed of Wilmette Bay attests the presence of icebergs in Glacial Lake Chicago when an abundant fauna flourished at Chicago. (Life of the Pleistocene, Plate VIII). We must consider, I think, that this life above the limestone in the Joliet quarry represents the biota that migrated up the Illinois and Desplaines rivers and reached Glacial Lake Chicago by way of the outlet via Joliet and Lemont. This time, therefore, could not be later than the Toleston, and was more likely during late Glenwood time, for a considerable fauna has been found in Chicago that lies between the Glenwood and Calumet stages (Bowmanville Low Water Stage). Of this biota, at least a dozen species are the same as those at Joliet. It is probable that these different stages could be worked out if sections were available, such as were studied during the excavation of the large drainage canals in Chicago. At Lemont, above Joliet, sections made with a post-hole auger showed

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about seven feet of marl and peat above the Niagara limestone, both the marl and peat containing an abundance of molluscan material.

Collections made in three places below Chicago indicate rather clearly that the Chicago biota migrated up the Illinois and Desplaines rivers. A comparison of collections made at Morris[1], Joliet, and Lemont[2] with those of Lake Chicago indicate this migration route.

The Joliet material contains more species because more thoroughly collected. The other localities would doubtless yield additional species with more time for collecting. The approximation of the Joliet species with those found in Glacial Lake Chicago at Chicago strikingly indicates that the Joliet fauna provided a reservoir from which the Chicago region was populated. The Morris material, though not large in number of species, contains some critical species which also occur in the deposits farther up the river. Additional collections from marl and peat deposits in the Illinois and Desplaines valleys will add more species records and strengthen the chain of migration. The following table graphically shows the relation of the Joliet species to the biota of the other deposits along these rivers:

Distribution of Aquatic Species in Different Localities

Species	Morris	Joliet	Lemont	Chicago
Sphaerium sulcatum	.....	×	.....	×
Sphaerium rhomboideum	.....	×	.....	×
Musculium secure	.....	×	.....	×
Pisidium variabile	.....	×	.....	×
Pisidium compressum	×	×	×	×
Pisidium pauperculum	.....	×	.....	×
Pisidium minusculum	.....	×	.....	×
Pisidium splendidulum	.....	×	×	×
Fresh water snails (Gastropods)				
Valavta tricarinata	×	×	×	×
Valvata lewisii	.....	×	.....	.....
Pomatiopsis lapidaria	.....	×	.....	.....
Amnicola leightoni	×	×	×	×
Amnicola lustrica gelida	×	×	×	×
Pulmonate Gastropods, aquatic				
Physa warreniana	.....	×	×	×
Physa gyrina	.....	×	×	×
Planorbis trivolvis	.....	×	×	×
Planorbis antrosus	×	×	×	×
Planorbis antrosus striatus	×	×	×	×

1. Made by Mr. H. E. Culver; see Journ. Geol., Vol. XXX, p. 58, 1922.
2. Baker, Life of the Pleistocene, p. 56, 1920.

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Distribution of Aquatic Species in Different Localities—Concluded

Species	Morris	Joliet	Lemont	Chicago
Planorbis campanulatu ferrissi	×	×	×	.....
Planorbis campanulatus	.....	.....	.....	×
Planorbis arcticus	.....	×	.....	.....
Planorbis deflectus	×	×	×	×
Planorbis altissimus	×	×	×	×
Planorbis parvus urbanensis	.....	×	.....	.....
Ferrissia parallela	.....	×	.....	×
Lymnaea stagnalis appressa	.....	×	×	×
Acella haldemani	.....	×	.....	.....
Galba caperata	.....	×	.....	×
Galba obrussa decampi	×	×	×	×
Galba elodes jolietensis	.....	×	.....	.....
Galba parva	.....	×	.....	.....
Galba dalli	.....	×	.....	.....
Galba obrussa exigua	.....	×	.....	×
Total species	10	32	15	24

The species included in the Ferriss collection are listed below with notes on the critical or interesting species. I am indebted to Dr. V. Sterki, of New Philadelphia, Ohio, for the determinations of the Sphaeriidae.

FRESH-WATER BIVALVES (PELECYPODS)

Sphaerium sulcatum (Lam.) Not common.
Sphaerium rhomboideum (Say). Rare.
Musculium secure (Prime). Common.
Pisidium variabile Prime. Rare.
Pisidium compressum Prime. Common.
Pisidium pauperculum Sterki. Abundant.
Pisidium minusculum Sterki. Very rare.
Pisidium splendidulum Sterki. Very rare.

FRESH-WATER SNAILS (GASTROPODS)

Valvata tricarinata (Say). Very abundant and fairly uniform. There is a tendency to lose the middle carina and develop into the variety below.

Valvata tricarinata perconfusa Walker. Uncommon. All individuals have the elevated spire and strongly carinate whorls of typical *tricarinata,* but the peripheral carina is completely lacking and there are no intergrades, as in *tricarinata.*

Valvata lewisii Currier. Rare, but one specimen found. The spire is low and the sculpture very fine.

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Pomatiopsis lapidaria (Say). Rare. The fossil form has deeper sutures than the recent form; specimens from loess-like deposits in northwestern Illinois (Stephenson Co.) are midway between the recent and marl specimens in this respect. The Joliet specimens are rather more widely umbilicated than the recent form.

Amnicola leightoni Baker. Common. *Leightoni* appears to be the common Amnicola of the Pleistocene, replacing *limosa* in many places, and to which it has previously been referred. There is some variation in the form of the aperture, a number of individuals having more shouldered whorls than the typical form as described from Ohio.

Amnicola lustrica gelida Baker. Abundant and variable. The Joliet Amnicolas are nearer typical *lustrica* than the lot from near Morris (the original locality for gelida), the spire being shorter and the body whorl wider. All have the thickened lip and more acute spire with deep sutures characteristic of *gelida*. (See Baker, Nautilus, Vol. XXXV, p. 222, 1921.)

PULMONATE GASTROPODS

Physa warreniana Lea. Common. The marl material is referred with some hesitation to *warreniana*. There is considerable variation in the height of the spire and in the width of the body whorl, the variation being toward an *ancillaria* type of shell.

Physa gyrina Say. Several small specimens are referred to this protean species, probably washed into the locality from some quiet pond-like area.

Planorbis trivolvis Say. A young individual only.

Planorbis antrosus Conrad. The form without spiral striation is rare in these marl deposits.

Planorbis antrosus striatus Baker. The majority of the marl *antrosus* are referable to the striate form.

Planorbis campanulatus ferrissi New Var. The shells from the Joliet marls are different from the recent form of typical *campanulatus*. The whorls are not as high, giving the shell the appearance of having a greater diameter and more whorls. The marl form is also smaller on the average and the aperture is not as widely cam-

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panulate as in the recent form. Specimens of each form are measured below, the recent form being from Canandaigua Lake, N. Y.

Whorls 5,	height 6.3;	max. diam. 15.7;	min. diam. 11.3 mm.	Recent.
Whorls 5,	height 6.0;	max. diam. 12.6;	min. diam. 10.0 mm.	Recent.
Whorls 5,	height 5.1;	max. diam. 12.6;	min. diam. 10.3 mm.	Marl.
Whorls 5,	height 4.6;	max. diam. 11.5;	min. diam. 8.5 mm.	Marl.

Planorbis deflectus Say. Not common. The form with the acutely keeled periphery.

Planorbis arcticus Möller. About a dozen specimens of a small Planorbis occur in the marl material that are indistinguishable from specimens of *arcticus* from the Great Slave Lake region. They were at first identified as *hirsutus* but are quite different from undoubted *hirsutus* from Massachusetts. It is not surprising that this Arctic species should be found in Pleistocene deposits, because the natural migration of these mollusks must have been by way of the Mississippi Valley and their remains would naturally be left in some of the ancient waterways. A single specimen of the same form was found in marl deposits near Rush Lake, Logan Co., Ohio, collected by Dr. M. M. Leighton. It was listed as *hirsutus* in Journ. Geol., Vol. XXVIII, p. 449.

Planorbis altissimus (Baker). Abundant and variable. This, the common small Planorbis of Pleistocene deposits, appears to be related to *arcticus* and is, perhaps, the ancestor of that species. As the latter is rare in Pelistocene deposits and common in the recent fauna in high latitudes this hypothesis seems reasonable. Numerous specimens of a small Planorbis from Devil's Lake and other places in North Dakota, collected by Miss Mina L. Winslow, of the Museum of Zoology, University of Michigan, are to be referred to *arcticus* and not to *altissimus,* as stated in a paper recently published (Journ. Geo., Vol. XXX, p. 54, 1922.) *Altissimus* is not surely known from the recent fauna.

Planorbis parvus urbanensis Baker. This, one of the smallest of the Planorbes, discovered in Pleistocene deposits near Urbana, was found to be fairly common in the Joliet fauna. As it has also been found in Carroll

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County it seems to have a rather wide distribution. Not yet reported in the recent fauna.

Ferrissia parallela (Hald.). Rare, but one specimen found.

Lymnaea stagnalis appressa Say. The rather poorly preserved material shows that this large Lymnaea was of good size as compared with the same species in the recent fauna. All of the specimens exhibit a peculiar malleation of the surface not seen in recent specimens. Two pieces of a large shell had this malleation so marked that it was at first identified as *Bulimnea magasoma* (Say). The presence of this marking on undoubted specimens of *appressa* indicates that this species also may bear these markings that are common on shells living in colder regions than the Chicago of today.

Acella haldemani (Desh. 'Binney). Four undoubted specimens of this somewhat rare Lymnaeid are in the Joliet collection. Compared with the recent form they are much smaller and the aperture is narrower. *Haldemani* is known in Illinois only from Cedar Lake, Lake County, where it is rare. (Baker, Bull., State Lab. Nat. Hist., Vol. VII, p. 103, 1906.)

Galba caperata (Say). A single specimen from the marl is smaller than most recent specimens. The spire is longer than in specimens now living in the same region.

Galba obrussa decampi (Streng). Very abundant and variable. Short spired forms of *decampi* have been referred to *galbana*. That species, however, has the inner lip turned back over the columella leaving but a small chink and forming, as Say remarked in his diagnosis, "the sinus of the fold very obvious". *Decampi* varies from a narrow to a wide shell, but the whorls are always distinctly shouldered, the umbilicus open, and the columellar lip forming a raised shelf over the umbilicus. *Decampi* is the common Pleistocene fossil of the central west while *galbana* is comparatively rare. The fossil *decampi* is much more variable than the form from the recent fauna, which is rare, the spire whorls being more pointed and the sutures deeper.

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Galba obrussa exigua (Lea). The fossils have deeper sutures and more shouldered whorls than the recent specimens.

Galba elodes jolietensis (Baker). Four small specimens appear referable to *jolietensis,* varying toward *elodes.*

Galba parva (Lea). The marl specimens are rather smaller than individuals from the recent fauna, showing variation toward a *dalli*-like form.

Galba dalli (Baker). Typical. One specimen is larger than any recent individual seen, measuring 5 mm. in length.

LAND GASTROPODS

Carychium exile H. C. Lea. Rare.

Vallonia gracilicosta Reinhard. Rare.

Succinea retusa Lea. Common.

Succinea avara vermeta Say. Rare.

Strobilops affinis (Pilsbry). Rare.

Strobilops labyrinthica (Say). Rare.

Pupoides marginatus (Say). Rare.

Vertigo ovata Say. Not uncommon.

Helicodiscus parallelus (Say). Rare.

Pyramidula alternata (Say). Common. The color markings are well preserved.

Pyramidula solitaria (Say). Common. The color bands are well preserved.

Gastrodonta ligera (Say). Rare.

Zonitoides minuscula (Binney). Rare.

Zonitoides arborea (Say). Rare.

Circinaria concava (Say). Not common.

Polygyra hirsuta (Say). Common.

Polygyra monodon (Rackett). Common. Some specimens are more globose with a higher spire.

Polygyra pennsylvanica (Green). Abundant.

Polygyra clausa (Say). Abundant.

Polygyra thyroides (Say). Not common. Fifty percent of the specimens have a tooth on the parietal wall.

Polygyra multilineata (Say). Common.

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Polygyra multilineata algonquinensis Nason. Rare. The small form is the same as the form described by Nason from Algonquin.

Polygyra multilineata (Say). A rare umbilicated form.

Polygyra profunda (Say). Common. Not different from the recent form. The color bands are preserved in some specimens.

Polygyra albolabris (Say). Rare.

From peat deposit near Sag Creek. Collected by J. H. Ferriss.

LAND GASTROPODS

Zonitoides minuscula (Binney). Rare.

Helicodiscus parallelus (Say). Rare.

Bifidaria contracta (Say). Rare.

PULMONATE AQUATIC GASTROPODA

Lymnaea stagnalis appressa Say. Not common.

Galba palustris (Müller). Abundant and variable.

Galba obrussa decampi (Streng). Rare.

Galba obrussa exigua (Lea). Rare.

Physa gyrina Say. Not common.

Physa walkeri Crandall. Rare. Spire longer than in typical form.

Physa integra billingsi Heron. Common and variable as to height of spire and width of body whorl.

Planorbis campanulatus Say. Common. A few specimens approach the form of the Joliet marls called *ferrissi.*

Planorbis trivolvis pseudotrivolvis Baker. Common. Very variable in height of whorls. This form seems to be the common large Planorbis of swamps and stagnant pools. It was evidently abundant during Pleistocene times.

Planorbis antrosus Conrad. Common. In the peat beds the form without spiral striae is the most abundant.

Planorbis antrosus striatus Baker. Rare.

Planorbis deflectus Say. Common. The peripheral carina varies from acute to rounded. None of the forms are the *hirsutus,* however.

Planorbis altissimus Baker. Not common and not as typical as the form in the Joliet marls.

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The peat deposits along Sag Creek represent a later time than the marl fossils at Joliet, and are probably to be classed with the deposits of the Englewood stage or the latter part of the Hammond stage. (Baker, Life of Pleistocene, pp. 57, 86, 88, 94.) The life of the two stations are practically identical as far as the critical species are concerned.

Mr. D. J. Fisher, of the Illinois State Geological Survey, has submitted for study several collections of Pleistocene Mollusca obtained from various places in the Joliet Quadrangle. These are listed below with notes on the species.

STATION NO. 1

Locality: Above old quarry in the SE part of Joliet, N. W. ¼, of S. E. ¼, Sec. 15, T. 35 N., R. 10 E.

Material: Calcareous marl.

Stratigraphic horizon: Wabash; Possibly the Bowmanville Low Water Stage.

MOLLUSCAN LIFE

LAND GASTROPODS

Pyramidula solitaria, common.
Polygyra thyroides, rare.
Polygyra clausa, rare.
Strobilops affinis, rare.*
Zonitoides arborea, rare.*
Succinea retusa, rare.

AQUATIC GASTROPODS

Valvata tricarinata, not common.
V. tricarinata perconfusa, rare.
Amnicola leightoni, not common.
Amnicola lustrica gelida, rare.

AQUATIC PULMONATES

Planorbis trivolvis, rare.
Planorbis antrosus striatus, common.
Planorbis campanulatus ferrissi, not common.
Planorbis altissimus, rare.
Planorbis deflectus, rare.

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Planorbis parvus urbanensis, rare.
Physa warreniana, rare.
Galba obrussa exigua, rare.

BIVALVES (PELECYPODS)

Sphaerium rhomboideum, rare.
Pisidium splendidulum, not common.

Two species of land shells, starred in the above list, occur in the Fisher collection that were not included in the Ferriss collection. On the other hand, 35 species occur in the Ferriss collection that are not in the Fisher collection. Mr. Ferriss collected the material many years ago when exposures were better than at present and also gave much more time to collecting, visiting the quarry many times. The marl material is commented upon on a previous page.

STATION NO. 2

Locality: Bank of DuPage River, S. W. ¼ of N. W. ¼, Sec., T. 35 N., R. 9 E., Joliet Quadrangle.
Material: Alluvial clay.
Stratigraphic horizon: Pre-recent.

MOLLUSCAN LIFE (LAND PULMONATES)

Polygyra clausa (Say), rare, *Succinea ovalis* Say, common.

STATION NO. 3.

Locality: South edge of southern slough, SE. ¼ of SW. ¼, Sec. 31, T. 36 N., R. 10, E.
Material: Alluvial clay.
Stratigraphic horizon: Pre-recent.

MOLLUSCAN LIFE (AQUATIC PULMONATES)

Planorbis trivolvis pseudotrivolvis Baker, not common.
Planorbis parvus Say, not common.
Physa gyrina Say, not common.
Galba elodes Say, not common.

These mollusks are such as live in swampy pools or sloughs where the water is more or less stagnant.

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STATION NO. 4.

Locality: Bank of Du Page River, SE. ¼ of SW. ¼, Sec. 16, T. 35 N., R. 9 E.

Material: Alluvial clay.

Stratigraphic horizon: Pre-recent.

MOLLUSCAN LIFE

Goniobasis livescens Menke, common.

Valvata tricarinata Say, rare.

Sphaerium stamineum (Conrad), common.

Planorbis trivolvis Say, rare.

Planorbis antrosus Conrad, rare.

Planorbis crista Linn., rare.

Polygyra thyroides (Say), rare, young.

This is a river fauna and is of the same general character as the river fauna of today in this region. The single specimen of *Planorbis crista* is peculiar in lacking the ribs which are characteristic of that species. This is the only specimen of this form observed among hundreds of specimens examined, both recent and fossil.

STATION NO. 6.

Locality: SW. end of southern slough, NW. ¼ of SE. ¼, Sec. 11, T. 35 N., R. 9 E.

Material: Alluvial clay.

Stratigraphic horizon: Pre-recent.

MOLLUSCAN LIFE

Planorbis campanulatus Say, rare, but one broken specimen found.

Planorbis antrosus Conrad, rare, one immature specimen.

Planorbis deflectus Say, common, the keeled periphery not as acute as in some recent forms.

Planorbis exacuous Say, not common, and typical.

Planorbis crista Linn., not common, with sharp, well defined ribs.

Planorbis altissimus Baker, abundant, somewhat resembling some forms of *parvus*.

Amnicola lustrica Pilsbry, rare and typical.

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Amnicola leightoni Baker, not common; somewhat resembling some forms of *limosa.*

Amnicola walkeri Pilsbry, common and typical.

Valvata tricarinata (Say), common and sharply tricarinate.

Physa warreniana Lea, rare, but one young specimen found.

Galba elodes jolietensis (Baker), rare, one young specimen found.

Pisidium splendidulum (Sterki), rare.

The above fauna is characteristic of a lake or large pond and not of a swamp, and probably represents a former large body of water connecting one of the stages of Glacial Lake Chicago. It is related in a general way to the fauna of the marls of the Joliet quarry.

STATION NO. 7.

Locality: Bank of DuPage River, SE. ¼ of NW. ¼, Sec. 10, T. 35 N., R. 9 E.

Material: Alluvial clay.

Stratigraphic horizon: Pre-recent.

MOLLUSCAN LIFE

AQUATIC

Goniobasis livescens (Menke), common.

Campeloma subsolidum (Anthony), rare.

Sphaerium stamineum (Conrad), rare.

LAND

Pyramidula solitaria (Say), rare.

Pyramidula alternata (Say), rare.

Polygyra hirsuta (Say), rare.

This is a river fauna, the land mollusks being washed in from the bank. The specimens are all normal and the same species now live in the vicinity.

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NOTE ON THE OCCURRENCE OF FUSULINAS IN THE PENNSYLVANIAN ROCKS OF ILLINOIS.

HAROLD E. CULVER, STATE GEOLOGICAL SURVEY, URBANA

1. Brief résumé of literature:

Probably the earliest reference to Fusulinas in the Pennsylvanian of Illinois is found in the reports prepared under the direction of A. H. Worthen. These record a large form, now known as Fusulina secalica, Say, in the rocks outcropping along Embarrass River in Cumberland County. There are references also to another and smaller fusulina called *Fusulina ventricosa, cylindrica,* var. but now known as Girtyina ventricosa, which was found in the limestone cap rock over No. 6 coal in Fulton County, in St. Clair County, and other districts farther south.

Udden reported Fusulinas from two zones in the rocks of the Peoria quadrangle. The lower of these was the limestone capping No. 6 coal and the other was the marl at the base of the Lonsdale limestone about 100 feet higher. The fossil in the lower zone was called *Fusulina secalica,* Say, and its abundance was noted. The Fusulina of the upper stratum was also listed as *Fusulina secalica,* Say, but with a parenthetical note suggesting an easily recognized distinction between the forms.

Two forms in similar relations were reported from the Belleville-Breese area. Here the zones were but half as far apart (50 feet), and the distinction between the Fusulinas was apparent. The upper was doubtfully referred to *Fusulina secalica,* Say, with a statement that it was a long, slender type, "quite different from the form of Fusulina found in the roof limestone over the Herrin coal".

The later references to Fusulinas in Illinois are in large part records of new occurrences of the Fusulina of the No. 6 horizon which were referred without particular investigation to the *Girtyina ventricosa* type.

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2. Matherville section:

During the field work last fall in preparation for a report on the coal resources of District III, Fusulinas were obtained from the cap rock of what was reported as No. 1 coal in the Pottsville series.

The section at Matherville where the Fusulina limestone is well exposed includes about forty feet of sandstone and sandy shale, with purer shale on top. Below is a dark, massive, argillaceous bed several feet thick, known to the miners as the "blue rock". Below this is the two foot, dark, argillaceous limestone which carries Fusulinas and which caps the coal of the region. Beneath the coal, which is here only 30 inches thick, is a sandy shale which grades to sandstone in less than a yard. Locally there are variations from this section. In southern Mercer County a second limestone and lower coal appear along Pope Creek. In eastern Rock Island County the upper sandy beds include layers and lenses of flint. In places the limestone cap thins out as though removed by erosion prior to the deposition of the overlying beds. A still more common variation is the presence of a few inches to several feet of shale between the coal and the limestone cap.

Disregarding these variations this same section appears in much of the adjoining area. Thus at the Alden Mine at Matherville, at the mines at Cable and Sherrard, at outcrops on Camp Creek in northern Mercer County, and along the Mississippi bluffs west of Andalusia, are found the blue rock, the Fusulina cap rock, and the coal.

Eastward the Fusulina limestone is found at Coal Valley and both north and west of Geneseo. Following the margin of the Pennsylvanian area southward the Fusulina limestone and associated beds are found in Warren, Knox, Fulton, and McDonough counties.

The Fusulinas appear to be restricted to the limestone overlying the coal, but are by no means uniformly distributed through even this thin stratum. They are most abundant in the lower part of the bed, although rarely found in the basal six inches.

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These are similar to the typical *Girtyina ventricosa* (Meek, von Staff) but are slightly smaller on the average. Considerable variation in size suggests the presence of more than one type, but all variations have been found in one bed. The noteworthy feature in this district is the apparent restriction of these Fusulinas to a single zone in the geologic section.

3. Other occurrences in the margin of the Eastern Interior Basin:

Besides the localities noted previously, lying in northwestern Illinois, Fusulinas have been found farther south near Camp Point in Adams County. The limestone here is an argillaceous rock, similar to that farther north, and the Fusulinas apparently are of the same variety as those in the Rock Island district, and these are tentatively referred to the *Girtyina ventricosa* type.

In southern Illinois, Fusulinas have been found in the limestone over what has been called No. 2 coal on Big Muddy River south of Murphysboro in Jackson County. Apparently the same type of rock and the same type of Fusulina appear here as along the western margin of the State.

On the eastern margin of the field very little work has been done, although Fusulinas have been found in a dark, argillaceous limestone overlying what appears to be No. 6 coal of the Illinois section on the Wabash near Perrysville and Cayuga in Fountain County. These occurrences suggest a continuity of this limestone throughout the Coal Basin.

4. Occurrences in the interior of the Illinois Coal Basin:

Recent examination of the core from Shelby County has shown Fusulinas at two distinct horizons. *Girtyina ventricosa* appears at its normal position in the limestone over No. 6 coal, and another form resemblng it but of different proportions and a suggestion of different interior structure is found in a more coarsely crystalline and purer limestone. This stratum lies 530 feet over the No. 6 cap rock and is tentatively correlated with the New Haven limestone of White County.

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Core from Hamilton County also shows two zones of Fusulinas which are here but 20 feet apart. These have not been carefully studied and the relations are not positively determined. The upper of the two limestones has been called the No. 6 cap rock. In the southwestern part of Montgomery County along Piasa Creek there have been obtained samples of Fusulina distinctly different from those of the No. 6 limestone. It is a long, relatively slender type which appears comparable to those reported from Belleville and from Peoria.

5. *Inferences as to distribution:*

1. It appears that no Fusulinas are found below the McLeansboro or possibly upper Carbondale beds.

2. There is at least one zone of Fusulina like *Girtyina ventricosa* lying distinctly above it near what has been called No. 8 coal. To this zone are referred tentatively the upper Fusulinas of Peoria, Belleville, and Shelby County, and those found on Piasa Creek.

3. There is but one zone yet noted of the true Fusulina represented by *Fusulina secalica* occurring high up in the McLeansboro series in Cumberland County. The true *Girtyina ventricosa* is to be restricted to the cap rock of No. 6 coal and to have a very wide distribution over the Eastern Interior Coal Basin.

6. *Implications as to correlation:*

1. There is no evidence to indicate that Girtyina ventricosa may not be retained as an index fossil for the cap limestone of No. 6 coal.

2. On this basis the margin of the Eastern Interior Basin is marked by McLeansboro beds rather than Pottsville and lower Carbondale.

3. This indicates a very extensive overlap of Late Pennsylvanian beds over the Pottsville and early Carbondale areas of deposition. This modification applies equally to Illinois, the Des Moines section in Muscatine and Scott counties of Iowa, and western Indiana.

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4. These features involve a reconstruction of structures where these have been based on the accepted correlation of coals. This is especially true near the margin of the basin where the correlation is less certain.

5. It appears probable that further search will reveal new zones of Fusulinas and that therefore the utility of these fossils as stratigraphic guides should be seriously questioned.

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PAPERS ON MEDICINE AND PUBLIC HEALTH

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THE PRESENT STATUS OF HOSPITAL STANDARDIZATION AND ITS VALUE TO THE PUBLIC

T. Arthur Johnson, M. D., Chief Surgeon, Sw. American Hospital, Rockford

For those not familiar with the Hospital Standardization movement, I wish first to present a brief history of its development.

A large number of national organizations interested in hospitals have become increasingly more concerned in the betterment of hospital service. However, before 1915 practically nothing definite had been evolved from the large amount of data which had been gathered on this subject by these organizations, the most active of which were The American Medical Association and The American Hospital Association.

The Hospital Standardization Conference held in Chicago, Oct. 20th, 1917 marked the beginning of active Hospital Standardization. This meeting brought together many of the leading hospital and medical men of the United States and Canada, including the presidents of the American Medical Association, the American Hospital Association and the American College of Surgeons. After considerable discussion of the various problems involved, Dr. Bevan recommended the creation of a general committee of twenty-five to bring together all the factors interested in the problem of Hospital Standardization, such as; The American Medical Association, the Association of the American Medical Colleges, the American College of Surgeons, the American Hospital Association, the State Licensing Boards, and all other large associations interested in this work.

At the close of this meeting a general committee was appointed to work out a definite questionaire and schedule for an extensive study of hospital conditions. This general committee was made up of the leading physicians, surgeons and hospital superintendents of the country. They met in Washington in December of 1917, and worked out a questionaire which was sent to all

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the hospitals and on the basis of the information thus obtained, the minimum standard was determined. Obviously, hospitals exist primarily for rendering the highest service to the patient, and this idea has been uppermost in formulating the minimum standard as will be seen by the following requirements:

THE MINIMUM STANDARD

1. That physicians and surgeons privileged to practice in the hospital be organized as a definite group or staff. Such organization has nothing to do with the question as to whether the hospital is "open" or "closed", nor need it affect the various existing types of staff organization. The word staff is here defined as the group of doctors who practice in the hospital inclusive of all groups such as the "regular staff", the "visiting staff", and the "associate staff".

2. That membership upon the staff be restricted to physicians and surgeons who are (a) competent in their respective fields and (b) worthy in character and in matters of professional ethics: that in this latter connection the practice of the division of fees, under any guise whatever, be prohibited.

3. That the staff initiate and with the approval of the governing board of the hospital, adopt rules, regulations and policies governing the professional work of the hospital: that these rules, regulations and policies specifically provide:

(a) That staff meetings be held at least once each month. (In large hospitals the departments may choose to meet separately).

(b) That the staff review and analyze at regular intervals the clinical experience of the staff in the various departments of the hospital, such as medicine, surgery, and obstetrics; the clinical records of patients, free and pay, to be the basis for such review and analyses.

4. That accurate and complete case records be written for all patients and filed in an accessible manner in the hospital, a complete case record being one, except in an emergency, which includes the personal history;

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the physical examination, with clinical, pathological, and X-ray findings when indicated; the working diagnosis; the treatment, medical and surgical; the medical progress; the condition on discharge with final diagnosis; and in case of death, the autopsy findings when available.

5. That clinical laboratory facilities be available for the study, diagnosis, and treatment of patients, these facilities to include at least chemical, bacteriological, serological, histological, radiographic and fluroscopic service in charge of trained technicians.

These standards have been made high enough to protect the patient and low enough to be reached by the majority of hospitals, whose motives are high. The college sums up the "Minimum Standard" in the following statement: "It grew out of the straight thinking of the clearest minds in medical and hospital work on this continent. It is practicable, workable and constructive. It costs effort rather than money. It safeguards the care of every patient admitted to the hospital by insistence upon competence on the part of the doctor, by thorough study and diagnosis in writing of each case, and by a checking up at least once each month of the clinical service of the hospital. It fixes responsibility through-out the hospital. It defines the minimum service to the patient which beyond all debate is considered essential".

In an article published in the Word's Work in June of 1920 on the effect of this standard among hospitals, Mr. Hawthorne Daniel says in part: "The statement is simplicity itself, and yet with all its simplicity it contains just the suggestions that go to make good hospitals of mediocre ones; just the suggestions that lead to the conservation of lives and the elimination of unnecessary operations; just the suggestions that bring about the conscientious care that every patient in every hospital has a right to expect."

Within the brief period of three years, practically all of the national associations interested in hospitals have

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accepted and endorsed the "Minimum Standard". These include the following:

The American Hospital Association.
The Canadian Medical Association.
The Catholic Hospital Association.
The Conference Board of Hospitals, and Homes of the Methodist Church.
The Medical and Surgical Section of the American Railroad Association.
The Methodist Hospital Association.
The Protestant Hospital Association.
The American Conference on Hospital Service.

We see therefore that this modern movement for hospital betterment and classification is not the work of a single organization, but represents the ideas and aims of all the large organizations interested in hospitals. Endorsing the "Minimum Standard" in 1919 Father Chas. B. Moulinier, President of the Catholic Hospital Association, made the following statement: "I pledge to the American College of Surgeons with my personal honor and all the official capacity I have, that the Catholic Association with whatever force and power it has, the clergy of the Catholic Church and that great body of twenty or thirty thousand sisters working in Catholic hospitals are going to co-operate with the College to the highest point."

The American College of Surgeons made a survey of all general hospitals of 100 or more beds in the United States and Canada in 1920, and they are now making a survey of all general hospitals between 50 and 100 beds. All hospitals which conform to the "Minimum Standard" will be rated as Class "A".

The progress of the movement has been rapid. In 1918, only 89 of the 761 larger general hospitals met the "Minimum Standard". In the next year, 198 fulfilled the requirements. In 1920, 407, and in 1921, 579 or 75% of the larger general hospitals had conformed to this standard. 25% of the 764 smaller hospitals already visited were found to meet the standard.

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In expressing his opinion on the rapidity of this movement, President Henry S. Pritchett of the Carnegie Foundation said: "From coast to coast the idea is changing the conditions in hospitals. Everywhere there is the ferment of development, the activity of improvement. In great centers of medical affairs the changes have been startling. In Baltimore, there is not a hospital of 100 beds or more that has not put into effective operation the "Minimum Standard", and in New York and other cities the hospitals have made almost as great an advance. The world of the hospital is changing. An advance normally to be expected in twenty years has come in three." The change in Canada has been just as rapid. In five provinces not a single large hospital remains unclassified.

No movement is destined to contribute more to the conservation of the public health of the country than the hospital standardization movement.

In 1917, the records kept in 75% of the hospitals of this country were practically valueless. No examinations were made of the patients on admission. No diagnosis, no family history and no physical examination were recorded.

Figures from two prominent hospitals prepared on similar cases before and after standardization show that the percentage of operative cases was reduced from 44 to 30% in one hospital, and in another from 62 to 47%, and the mortality was reduced about 1%. This represents the prevention of 15% of unnecessary operations and the saving of one in a hundred of all patients admitted.

Again, a comparison of a standardized and a non-standardized hospital in which 100 appendectomies were done showed the following:

	S	N. S.
Complete physical examination and blood count	100	14.
Consultations held	41	2.
Working diagnosis reported	100	0.
Progress notes recorded	100	0.
Infections following operation	3	12.
Incorrect diagnosis	4	14.
Patients relieved	94	77.
Deaths	2	9.

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These figures show in end results in favor of the standardized hospital a 7% lower death rate, and 17% more of relieved patients.

Our community of about 90,000 people is cared for by 310 general hospital beds. Last year 7,628 patients were treated in the three local hospitals. Of these, 4,106 or 53% were surgical cases and 1,753 or 23% submitted to major operations.

Conservative estimates show that the application of the principles of standardization reduces the death rate at least 1% and unnecessary operations at least 5%.

This would mean the saving of 76 lives and the prevention of 381 unnecessary surgical operations each year in Winnebago County alone.

As applied to Illinois, this would mean the annual saving of 4,000 lives and elimination of 20,000 needless operations.

About 6,000,000 people are treated in the general hospitals of the United States each year. Based on the above percentages, standardization will mean an annual saving of 30,000 lives and 300,000 needless operations in the United States.

During the twenty months of our active participation in the recent world war, about 80,000 of our soldiers died of disease or wounds received in battle. According to our figures, more than half as many lives will be saved in an equal period through this hospital movement.

Nothing has been said about that large number of obscure surgical conditions which will be discovered and corrected by a more efficient diagnosis and treatment. Most of these border-line cases have here-to-fore received very poor medical care or no treatment at all.

We can easily comprehend the far reaching results of the application of the principles of standardization to all the hospitals of the country.

1. It will result in abler diagnosis and more intelligent treatment by a more efficient medical profession.
2. It will help greatly to eliminate incompetent operators and unnecessary operations.
3. It will do more than legal enactments to abolish the evil of fee-splitting.

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4. It will produce a better trained nursing profession and will help greatly to disseminate useful knowledge of disease and its prevention and cure to the public.

5. It will lower the death rate, reduce the number of post-operative complications and lessen the period of disability of the sick.

6. Indirectly, the influence for good will extend far beyond the walls of our hospitals into the homes of all of our people.

7. It will change many of our hospitals from poor boarding houses into scientific institutions.

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RELATION OF THE HOSPITAL TO THE COMMUNITY

WALTER G. BAIN, M. D., ST. JOHN'S HOSPITAL, SPRINGFIELD

The relation of the hospital to the community may never have seemed a matter of much importance to you. Sooner or later, however, you, or some one near and dear to you, will, in all probability become so ill that your interest in the hospital question will be paramount for the time being to all other interests. For the reason that modern scientific practice of medicine demands hospitalization of the sick, the question of the relation of the hospital to the community is a matter which should concern every layman and every physician. Hospitals very frequently are supported by contribution from the public. This phase of the question should make it a matter of added interest to you. It is in the belief that both yourselves as possible future patients, and the hospital as a present community problem, will be benefited by the views of one who has made some study of these relations that I undertake to discuss the present hospital situation.

That the hospital has become a matter of interest to the medical profession and to the hospital world at this time has been brought about by the very active campaign of the American College of Surgeons to make the hospital a public issue. In this campaign they have spent much money and have carried on an extensive propaganda to impose their views on the public.

The recent legislation, and the establishing of nurses' examining boards, and state and government inspection of hospitals, with a view to the registration of nurses and the use of hospitals for the care of government patients, have, without a doubt, had a tendency to call the attention of hospital boards, governing bodies and managers to certain fundamental deficiencies and neglects. The College of Surgeons unfortunately have adopted a standardization program which will tend eventually to undermine the proper relation of the hospital to the community and thereby weaken the hospital movement by

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curtailing the hospitalization of the sick, rather than increasing it.

Inasmuch as the standardization program as outlined by the College of Surgeons applies almost entirely to the conduct of physicians and surgeons and not to the better organization of the hospital, it appears to me that this program puts the hospital in the position of policing the medical profession instead of serving it. The standardization program calls for five rules with which the hospital is supposed to comply. If the hospital governing bodies undertake compliance with these rules they must change their fundamental relations to the medical profession. They must change their fundamental relations from that of serving to that of dictating to the physician.

THE MINIMUM STANDARD OF THE AMERICAN COLLEGE OF SURGEONS

1. That physicians and surgeons privileged to practice in the hospital be organized as a definite group or staff. Such organization has nothing to do with the question as to whether the hospital is "open" or "closed"; nor need it affect the various existing types of staff organization. The word staff is here defined as the group of doctors who practice in the hospital exclusive of all groups such as the "regular staff."

2. That membership upon the staff be restricted to physicians and surgeons who are (a) competent in their respective fields, and (b) worthy in character and in matters of professional ethics; that in this latter connection the practice of the division of fees, under any guise whatever, be prohibited.

3. That the staff initiate and, with the approval of the governing board of the hospital, adopt rules, regulations, and policies governing the professional work of the hospital; that these rules, regulations, and policies especially provide: (a) That staff meetings be held at least once a month. (In large hospitals the departments may choose to meet separately). (b) That the staff review and analyze at regular intervals the clinical experience of the staff in the various departments of the hospital,

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such as medicine, surgery, and obstetrics; the clinical records of patients, free and pay, to be the basis for such review and analysis.

4. That accurate and complete case records be written for all patients and filed in an accessible manner in the hospital, a complete case record being one, except in an emergency, which includes the personal history; the physical examination with clinical, pathological, and X-Ray findings, the treatment, medical and surgical; the medical progress; the condition on discharge, with final diagnosis; and in case of death, the autopsy findings when available.

5. That clinical laboratory facilities be available for the study, diagnosis, and treatment of patients, these facilities to include at least chemical, bacteriological, serological, histological, radiographic, and fluoroscopic service in charge of trained technicians.

The first rule relates to the organzation of the attending hospital men. The organization of the attending physicians of any hospital, if such organization is necessary, ought to be effected among those physicians independently of the management of the hospital, if it is for their medical uplift.

There are certain inherent fundamental rules with which it is necessary for every hospital to compel the medical profession to comply, but it is not necessary for the hospital to enter into an organization with the medical profession to determine these rules, such as those relating to the admissions of infectious diseases and the like.

The second rule relates to the competence of the attending staff. My contention is that whatever relates to the competence of a physician concerns the department of the government which licenses him to practice and does not concern the authorities of the hospital, who often times are laymen and are not competent to pass on the professional qualifications of physicians.

The third regulation refers to the supervision of the professional work in the hospital. To justify such supervision, it must be presumed that the stamp of efficiency

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given a physician by the state is inadequate. From this rule the very delicate question arises as to who is competent among the physicians of the community to judge and pass on the efficiency of their confreres. Another difficulty arises: How is the community to be assured that the stamp of approval or disapproval of the committee supervising the work of the physician will not be made according to the selfish interests of the staff? Still another difficulty which arises is, how is such a staff once appointed, to be deposed, or replaced when other better qualified physicians come into the community, or when the acting men grow old and less competent?

The third regulation also calls for meetings of the medical men. Such meetings can easily be arranged for under the auspices of the local medical society if that is not already being done, under whose auspices special meetings can be set aside for the review of hospital cases and records, if such meetings are for the best interests of the medical profession. As to the advisability of reviewing and analyzing clinical records, each physician would know whether or not he was violating the confidence of his patient in so doing, whereas the hospital authorities have no way of judging, and have no legal right to permit the information contained in the records of the patients to become the common knowledge of the medical profession of the community and hence are not in a position to enforce such a rule.

The fourth rule is that of compiling of case records. This requirement is wise and advisable, but not necessary in every case to good medical treatment. The character and completeness of such records as well as the future use of the same are entirely dependent upon the personality of the physician in charge of the case, and are quite foreign to any interest of the hospital authorities except in so far as the hospital clerical force is called upon to file and index the records that originate in the hospital.

The fifth requirement may or may not be closely related to the hospital management. This is the requirement for the provision of a clinical laboratory. Such a

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laboratory should be in charge of a medical man. The hospital has two alternatives, the first, to rent space suitable for such facilities to a physician who will undertake to install his own equipment; the second, for the hospital to purchase and install equipment and arrange a suitable basis for the conduct of this department under a competent man. In either case the hospital is only responsible from a financial standpoint, and a physician from a professional standpoint.

If the hospital authorities undertake to enforce this standard of the American College of Surgeons they must take the position of self appointed censors of professional men already licensed by the state. With the possible exception of the last one, all the rules of the Minimum Standard should be enforced by the state, or by the physicians of the community organized as the County Medical Society; thus relieving the hospital authorities from acting as police of delinquent medical practitioners.

In the hope that I may make plain to you the effect of the adoption of this standard, I wish to suggest a classification of hospitals under three types.

What I will designate as Type I is necessarily an autocratic type of hospital management. The type that I will designate as Type II shows the relation of hospital authorities to the medical profession and to the prospective patient which I believe to be ideal from the standpoint of all concerned, and which is the type of organization of St. John's Hospital, Springfield, Illinois, which later I wish to discuss in detail. The type which I will designate as Type III shows the possibility of hampered relations of hospital management, unfair discrimination against licensed physicians and against prospective patients, when hospital authority is shared with a hospital staff.

The first type of hospital has for its aim and purpose other functions in addition to the care of the sick of the community. In addition to the work of caring for the sick, some hospitals of Type I function as teaching institutions, in which case the organization must be similar to that of the teaching institutions with which they are

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affiliated. Others of the first type, though concerned only with the care of the sick, have their origin and control bound up in Federal, State, County, or Municipal government. A third group of the first type are private hospitals owned and controlled by physicians for the care of their own patients.

Any one group of the first type of hospitals requires a form of organization essentially different from the hospital whose function is solely to care for the sick of the community.

The first type of hospital charged with a definite purpose is usually under control of a director, officer or manager who is especially trained to direct the functioning of the hospital along the lines necessary to obtain the end desired. Such an officer is usually found to be a medical man. He is charged not only with the care of the sick but is also responsible for the physical property, and for the professional and moral conduct of the medical and nursing personnel. Such an officer must have definite, limited and lawful authority over the personnel. He therefore builds up an organization which will function and carry out his ideals of hospital organization and care of the sick. Thus he will surround himself with such a personnel as are willing to act in accord with his plans. The results obtained are credited to the one source.

Except as it is necessary to use the Type I organization for comparison, my paper is not concerned with this type, nor have the activities of the self appointed hospital standardizing bodies of the American College of Surgeons been concerned with it, except that it is apparently their aim to bring about the organization of all hospitals according to this type and to place themselves in control.

The second type of hospital is organized, presumably, for the sole purpose of caring for the sick of the community. Such hospitals are usually dependent upon gratuities from the public, or patronage from the public for their financial existence and support. Whether they are brought into existence by a society or a religious

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order or by a board of public spirited citizens, this fundamental obligation of taking care of the sick of the community still exists. Every citizen of the community in which such a hospital is brought, should have, theoretically, equal privileges. By privileges I mean the right to receive medical care and nursing in the institution when the emergency or demand affecting him or his family arises. Assuming that his demands are consistent with the hospital organization, and assuming the semi-public character of these institutions and the right of the public to be served in them, the question of organization to meet this condition comes into consideration. We have two distinct divisions of the activities to be organized. First, organization from the standpoint of housing, boarding, and supplying nursing care; second, the organization of the medical care.

The third type of hospital is similar to the second type in its fundamental obligations to the medical profession and to the public. To show the potential danger of failure to maintain this fundamental relation in a hospital where a staff functions, I wish to draw comparisons between the Types II and III hospitals.

The issues at stake are these: shall a hospital where physical existence is controlled by a non-medical personnel and which is dependent on the public for its support place itself under the control of a limited group of medical men, or shall it function separately and independently of the medical profession, granting equal privileges to all members of the medical profession of the community? Will the interests of the public be served best by selecting a group of medical men to take over control, or by organizing the hospital in such a way that all medical men have equal privileges? Under the Type I hospital the functioning of the hospital always progresses in accordance with the ideals of the men in charge. In the Type II hospital each patient is cared for according to the ability and ideals of the attending physician of his choice. In the Type III hospital only the physicians in control of the hospital are privileged to practice their profession to the full extent granted them by their li-

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cense received from the state, while the physicians not on the staff of the hospital are limited in their hospital practice by the privileges granted them or denied them by the group of men who are fortunate enough to be on the hospital staff. Thus from the standpoint of the medical man who is not on the hospital staff, though he live under a democratic government, which licensed him to practice medicine and surgery, his professional life is controlled, in so far as his patients require hospital care, by an autocratic group of men, the Hospital Staff, whose authority he resents to the extent that he will habitually refuse hospitalization of his patients except in the most extremely urgent cases, this to the detriment of the hospital, himself and his patients. When one considers that if the application of the Minimum Standard be universally adopted by hospitals, not more than 15% of the medical profession can hold hospital staff positions, one can foresee this, that 85% of the medical profession will be constantly advising against hospitalization rather than for it. The more prosperous physicians without staff positions will endeavor to establish private hospitals for their patients which will, if they succeed, necessarily be more expensive, less well equipped, consequently less efficient than the larger hospitals from which they are barred and which are given public support. The foregoing comparisons of hospital organizations are graphically brought out in the following charts:

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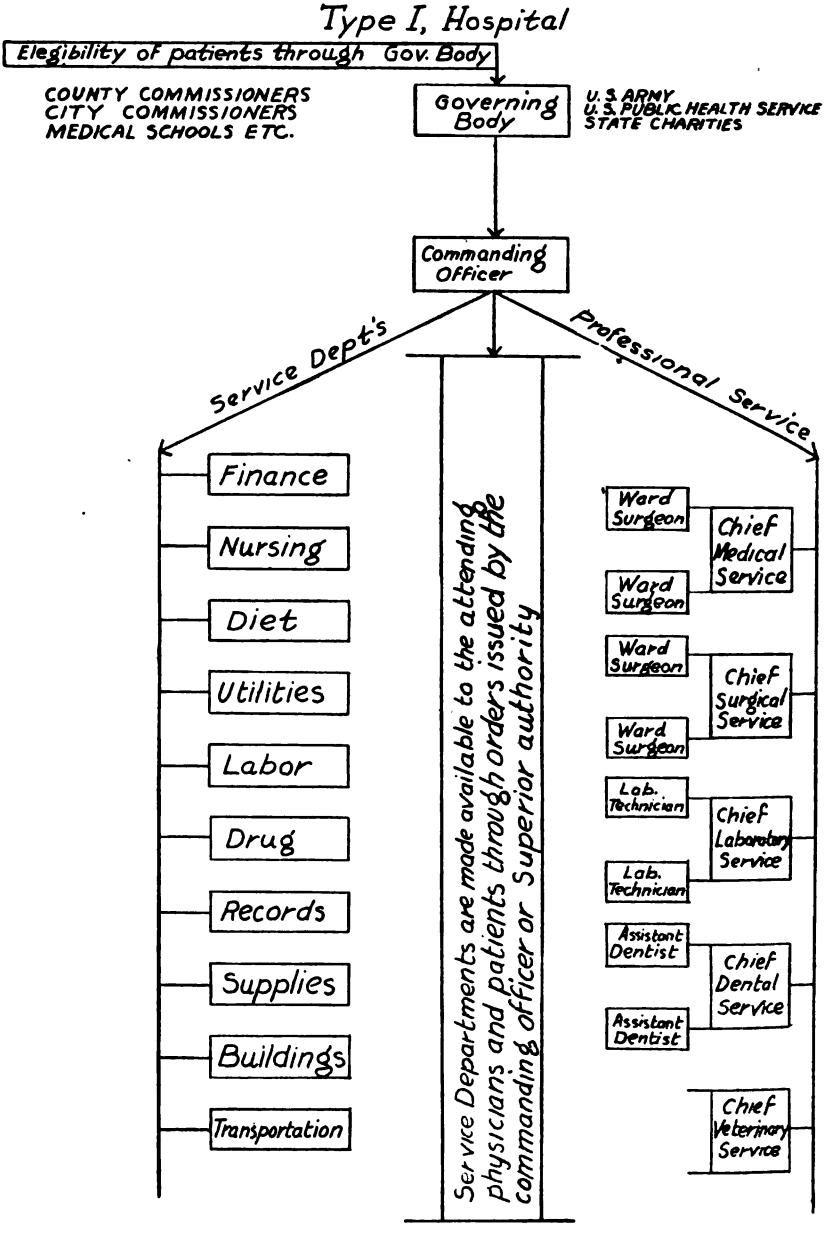

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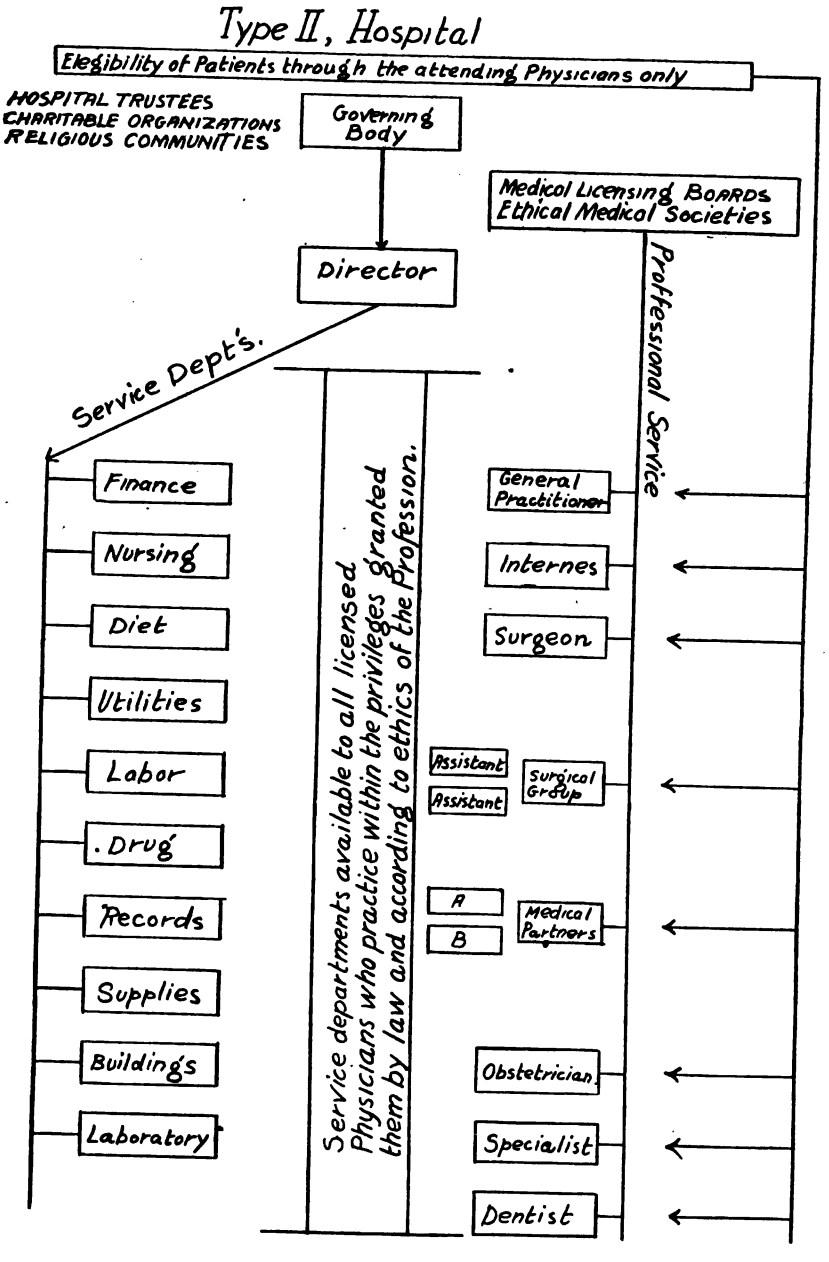

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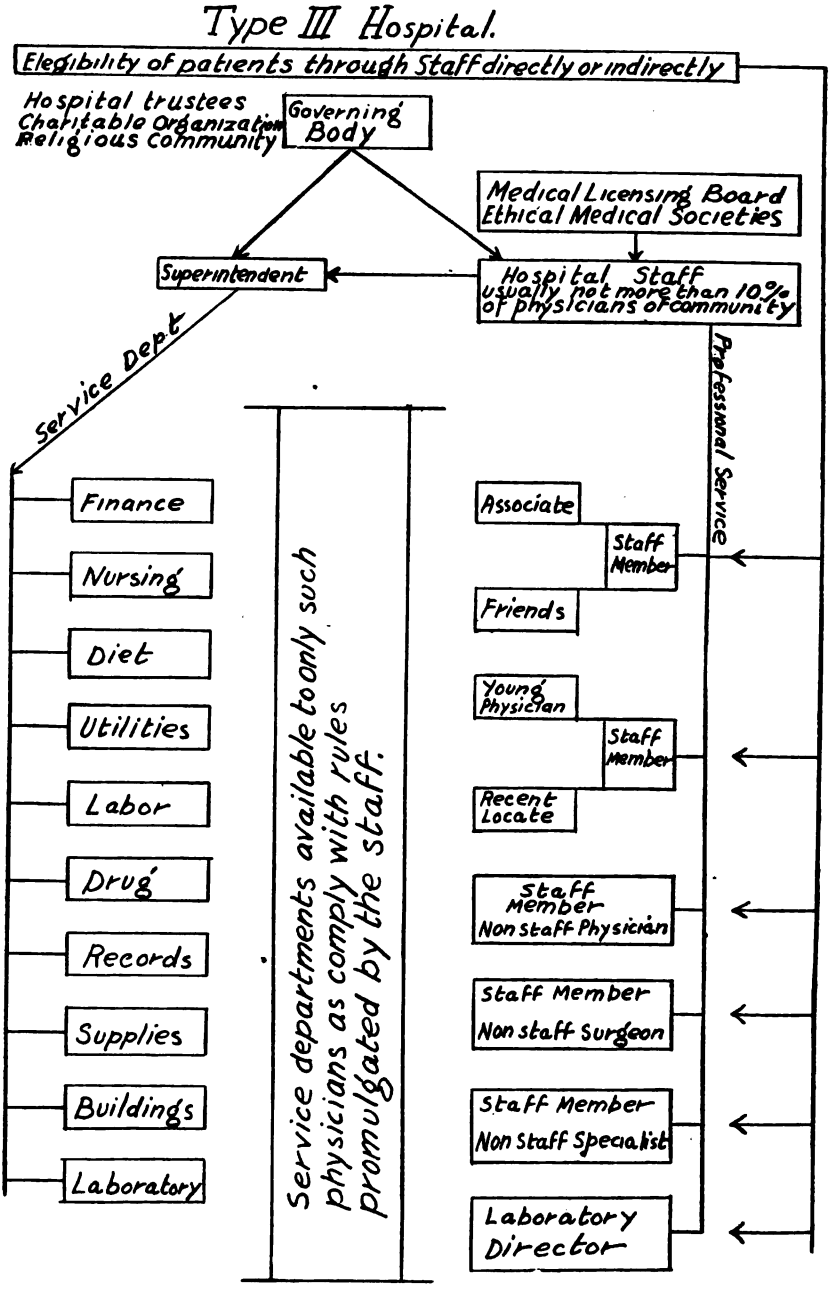

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There follows a tabulation of the essential differences between the three types of hospitals:

1. *Source of Control.*

TYPE I	TYPE II	TYPE III
Hospitals under control of Federal government, State, or Municipality, or private institutions owned by physicians or hospitals allied with teaching institutions and utilized for teaching purposes.	General hospital supported by the community under control of a charity board, a religious community, or owned and controlled by a religious organization.	General hospitals supported by the community under control of a charity board or owned and controlled by a religious organization or a religious community, but under the direction of a staff of local physicians selected by the Board or Community who make themselves responsible for professional work in the hospital.

2. *Relation of Attending Physicians to Management.*

Attending staff selected by Commanding Officer according to existing laws of the state or allied teaching institutions or by owners.	Attending physicians all licensed physicians practicing in accordance with laws of the State and the ethics of the profession.	Attending physicians selected by the attending staff.

3. *Limitation of Medical Personnel.*

Personnel limited by law.	Medical personnel limited by Medical Practice Act and existing code of Medical Ethics.	Medical personnel limited by judgment or prejudices of Medical Staff.

4. *Responsibility for Medical Care of Patients.*

Governing body responsible for patient.	Patients' physician is solely responsible for the patients' professional care.	Staff of physicians responsible for professional conduct of patients' physician.

5. *Responsibility for Financial Management.*

The governing officer responsible for financial management.	Governing body retains financial management or delegates same to business manager.	Financial manager subject to more or less interference by medical staff.

6. *Responsibility for Physicians' Professional Qualifications.*

Governing officer responsible for qualification of physicians under him.	State responsible for qualifications of attending physicians.	Staff responsible for qualifications of attending physicians.

7. *Legal Responsibility for Patients.*

Legal responsibility rests with governing officer.	Legal responsibility rests with physician selected by the patient.	Legal responsibility rests with hospital and with the staff.

8. *Source of Financial Support.*

Financial support obtained through taxes, from allied teaching institutions or from fees paid by patients.	Financial support obtained from public contributions, from services of religious communities and moderate fees from patients.	Financial support obtained from public contributions, from services of religious communities and moderate fees from patients.

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9. *Attitude of Medical Profession Toward Method of Appointing Physicians.*

Medical profession generally recognize justice in selection of medical personnel as done in accordance with government laws.	Medical profession appreciate general recognition enjoyed by them.	Medical profession jealous and embittered by selection of a favored group placed in control over them.

10. *System of Selecting Medical Personnel.*

System of selecting medical personnel works no hardship.	System of selecting medical personnel works no hardship.	System of selecting personnel gives rise to unfair discrimination against physicians not on the staff in that their practice is limited by lack of hospital facilities.

11. *Relation of Community to Hospital.*

No patient needing medical care excluded except by law.	No patient is excluded for any reason whatever, except by general hospital order against criminal surgery and contagious diseases.	Any patient excluded unless willing to replace their family physician by one of the hospital staff, or have family physician work under direction of staff.

12. *Relation to Growth of Hospital.*

Growth of institution not dependent on character of medical personnel.	Growth of institution concurrent with growth of community.	Growth of institution is dependent on popularity of attending staff.

Up to the time the Nurses' Examining and Licensing Boards were being established, little interest had been taken in the analysis of the hospital situation, either by the medical profession or by the public. This agitation has stimulated both medical and hospital organizations to efforts resulting in the collecting of much data on the subject, and to the publication of much information which has made it possible for hospital superintendents to analyze local situations by reliable comparisons. Coincident with the standardization program of the American College of Surgeons and often confused with it, has arisen a number of other movements of interest to the medical profession. Of these I wish to mention Group Medicine and the Municipal Hospital movement. Under the name of Group Medicine, we have, during the last few years, seen the establishment of a great many so-called clinics. Under the name of Clinic, an internist, a surgeon, a pathologist, a roentgenologist, and other specialists, combine to form a partnership in practice, ostensibily to reduce their overhead expense and to give more complete service at a lessened cost to the patient. Occasionally these clinics have established their own hos-

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pital or have gained control of the staff of an existing hospital of the Type III, just described. The Municipal Hospital movement has been brought about by those physicians and public spirited citizens who sensed, if they were not fully cognizant, of the unfair discrimination of the Type III hospitals.

In view of the fact that in the organization of St. John's Hospital, of Springfield, Illinois, we believe that we have met satisfactorily these three most important problems, I would like to take up the story of the way this has been done. From the standpoint of the Minimum Standard, but without a staff, we are able to give equal privileges to physicians, to give the patient the freedom in his choice of a physician, to give the greatest scientific care to the patient, to bring about with the greatest ease interchange of opinion among physicians, to give the greatest facilities for consultations, and to establish a very satisfactory system for maintaining present and future records, and we are maintaining unexcelled laboratory facilities, and an X-Ray department of the highest type. From the standpoint of Group Medicine, the hospital organization has offered every convenience for supplementing the efforts of several clinics. From the standpoint of the Municipal Hospital, the demands of the public and of the profession have been met by maintaining every requirement from the Free Dispensary to the most satisfactory type of private room.

Inasmuch as the hospital has passed through the period of organization under a closed staff, the period of a partly closed and open staff, and a long period of organization without a staff, we feel that our experience justifies us in speaking with authority on the advantages of each type. As evidence of the growth of the institution, through these varying periods, I wish to submit the following chart.

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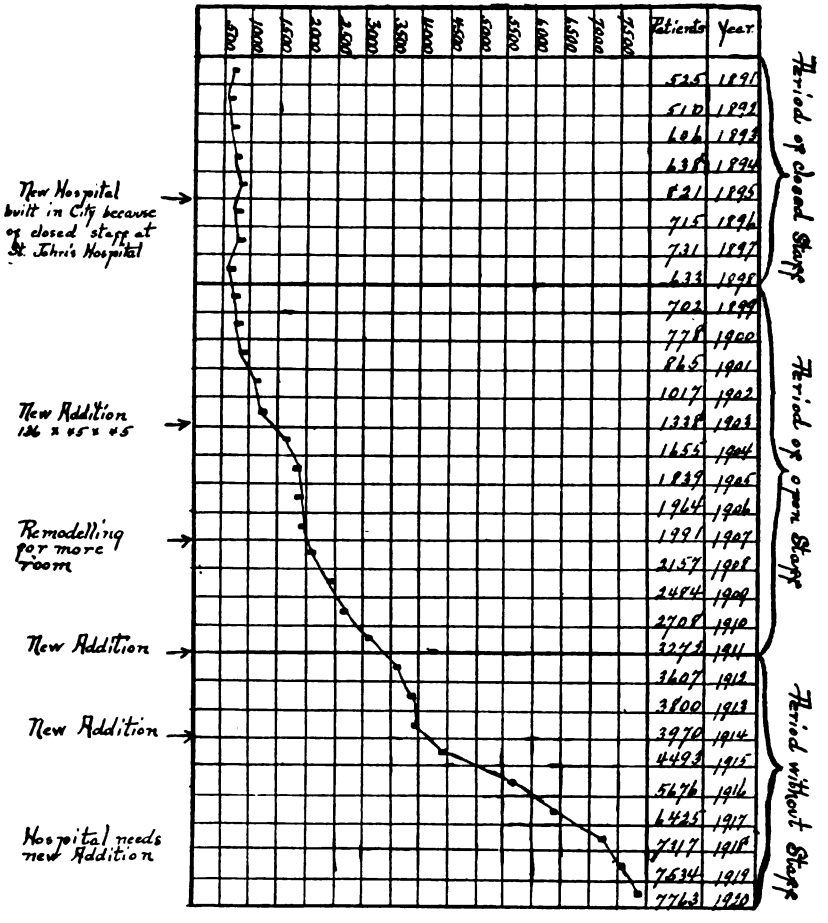

This hospital is typical of the hospitals of many communities and is typical of the average community of the same size in any state. The growth of our hospital however has been remarkable, and the results have been satisfactory from the standpoint of the care of the sick of the community, the percentage of patients hospitalized, the relations of physicians to the hospital and to each other, and also from the standpoint of the advantage to the community in getting good care at the minimum expense to the patient. These advantages have been such that I believe it to be quite worth while for me to take up an intimate discussion of this institution.

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From the standpoint of the relation of the population to the hospital beds as compared to the hospitalization in other communities, I would like to present the following table, the data for which was obtained from the Journal of the American Medical Association.

(Reference data obtained from American Medical Association Journal, April 16th, 1921, page 1085.)

RATIO OF HOSPITAL BEDS TO POPULATION.

Unit of Population	Area of Sq. Mile	Ratio of Beds to Population	Population
N. Atlantic States	161,976	242	.....
S. Atlantic States	209,071	508	.....
N. Central States	756,368	355	.....
S. Central States	609,255	705	.....
Western States	1,177,220	211	.....
All States	2,973,890	340	.....
New York City	.....	232	5,621,000
Holyoke, Mass.	.....	183	60,000
Baltimore, Md.	.....	112	584,605
Wheeling, W. V.	.....	111	56,000
(Has nine general hospitals containing less than 25 beds)			
Chicago, Ill.	.....	214	2,701,705
Rockford, Ill.	.....	169	65,000
Springfield, Ill. **	.....	95	59,000
New Orleans, La.	.....	399	387,408
Chattanooga, Tenn.	.....	151	58,000
Los Angeles, Calif.	.....	211	575,480
Sacramento, Calif.	.....	137	65,857
8 largest western cities	.....	164	.....
8 largest eastern cities	.....	175	.....

From this table it will be seen that the community in and around the city of Springfield has one hospital bed to each ninety-five of the population, which shows a greater hospitalization demand than any other district of the United States; one hundred per cent higher than any single state in the United States, and a greater percent than any other city. I attribute the low hospitalization in the southern district to the colored population. The discrepancy in the east is without a doubt due to the system of closed staff hospitals which increases non-hospitalization of patients on the part of physicians not on the hospital staffs.

It will be noted from these statistics that the western cities have a larger hospitalization than those of the east.

** Since these figures have been made 100 beds have been added, and a new addition is under construction which will give 75 more, making the ratio of beds to population 75.

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This is due to the more liberal hospital facilities offered the physician, as many of the western hospitals are without a staff or with a distinctly open staff.

Discussing the Springfield situation, we have in the city a competing general hospital with a staff organization, but this has not tended to curtail hospitalization in the community because of the liberal policy of St. John's. We have also a private hospital for nose and throat cases which has always been filled, owing to the wide professional reputation of the owner and manager. We have also two tuberculosis hospitals, which are also privately owned and are well patronized.

Discussing the operations of the hospital from the standpoint of the Minimum Standard, let me state how these requirements have been met. First, assuming that the organization of the attending men, as suggested, is for the purpose of bettering hospital conditions, how have hospital conditions been bettered without such an organization of physicians? It has been done in this way; whenever the attending men have desired improvements or changes which would tend, as they believed, toward the betterment of their professional work, their requests have been made direct to the Director as individuals, or through the hospital personnel. Such requests have been studied from the standpoint of the hospital facilities and policies, inquiry has been undertaken as to the workings of such improvements in other institutions, and the suggestion, wherever feasible and consistent with the financial policy of the institutions, has been carried out. Thus, suggestions have not come from a small group, but the hospital has received suggestions from the entire medical personnel of the city. It might here be stated that the medical personnel of the attending men of the hospital includes every registered physician in the city, who is either a member of the County Medical Association, or who is found from time to time in consultation with members of the County Medical Association.

With reference to the competence of the attending men, the Director of the hospital has always taken the stand that the competence of a physician to practice medi-

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cine should be determined by the state, and not by the hospital authorities.

It has happened occasionally that the nursing personnel of the hospital has observed certain younger men, who though deemed competent by the state licensing board, have undertaken the performing of surgical procedures for which they were obviously not fitted by experience. When such observations have been made, the man was requested by the Superior of the hospital to associate himself in future undertakings with some one more experienced than himself. It has never been necessary to refuse these men the operating room, as they have always willingly complied with this request, and in fact have seemed grateful that such a request has come from the Superior of the hospital without having their incompetence advertised among their professional brothers. Apparently these men have held no ill will toward the hospital, and have in the future always limited their surgical efforts to work quite within their ability. The fact that they were not forced to associate themselves with any man or group of men, and that they were not forced to relinquish control of their patients, has given these men a freedom of professional action quite satisfactory to themselves, to their patients, and to the hospital authorities.

As to the third standard, the hospital authorities have always reserved the privilege of refusing classes of cases where there was even a doubtful criminal intent. In such cases, the authorities, if they were at all suspicious, have either refused the care or have insisted upon consultation with men of known integrity. It has been very noticeable that after one or two attempts of this kind, the black sheep of the profession have never given any trouble.

In cases of suspected epidemic diseases, consultations have been insisted upon and obtained without embarrasment to the attending men and with what we believe to be a minimum disturbance to the hospital.

As for the meeting of medical men in conference, a club room has been provided in the hospital where the physicians have daily conferences and discussions of their cases. It is surprising to note the freedom with

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which all hospital matters and difficult cases are thrashed out among them in this conference room. These conferences are informal but from their frequency and from the apparent interest of those taking part, they are obviously of much benefit.

The younger men in this way daily get into conference about their difficult cases with the older men; the older men with each other about their difficult cases or cases of interest, and though informal, one can hardly conceive of a more advantageous arrangement. From these informal conferences there are daily bedside consultations and frequent surgical clinics attended by interested physicians. In my opinion such an arrangement is quite as beneficial as the formal review of cases in a called staff meeting.

With references to the compiling of case records, the hospital authorities have always insisted upon the greatest accuracy and completeness from the standpoint of the case record so far as the nursing personnel was concerned. It has also been an important point with the hospital to see that the physician place on the record his own orders for his patient. But in view of the fact that the patient was presumed to belong to the physician, the hospital has taken the attitude that the history, past and present, and the details of the physical findings of the case, were matters of professional concern and confidence between the patient and his physician. They have not insisted on this record being made, except as it was necessary for the hospital to have on file the summary of such information in the form of a tentative diagnosis, which is necessary for the proper classification of patients entering the hospital, and for the protection of the hospital against the admittance of infectious diseases. Similarly, records in regard to the operations have been required, where such records are necessary for the proper conduct of the operating room and for the classification of operations. The hospital has felt it advisable to furnish as complete mechanical arrangement as is necessary, but have only insisted on such records as are of value to the hospital personnel in their own work. Besides the foregoing records, upon the discharge of the

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patient the physician is required to report a summary of his treatment, condition of patient on discharge, and complications. All this information is summarized, and indexed for future reference, for other physicians readmitting the same patient and for the compiling of hospital reports.

It has always been the attitude of the hospital that beyond these requirements the information which a physician obtains from his patient relative to his condition is a confidential matter, and should only be placed in the records as the physician might desire.

St. John's Hospital has been one of the leaders in the matter of providing laboratory and X-Ray facilities, and through this department the hospital has not only met the demands for better scientific work, but has also been able to furnish the physician a means of meeting the demand for group medicine, and to a certain extent the demand for municipal clinics. The laboratory is so equipped that the physician can arrange to have whatever assistance he desires, from the bending of a test tube to the work necessary for a complete clinical study. The fees are so reasonable that clinical groups can better afford to patronize the laboratory at the hospital than maintain their own organization of this kind. This department also furnishes a center for conference and consultations. In addition to the already mentioned facilities, a free dispensary is in operation, which is maintained by the county, and where daily free clinics are held and where indigent patients are treated. With this sort of an arrangement, so flexible, so democratic, so convenient, available to every citizen through his physician, we believe we are able to meet the demands of group medicine, of the Municipal Hospital and of the highest standard of service.

The basic principles underlying this service are:

1. The St. John's Hospital is owned and conducted by the Hospital Sisters of St. Francis, who welcome all physicians that can give satisfactory proof of being in good standing in their profession.

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2. The patient belongs to the physician who alone is responsible for his professional work.

3. The hospital is responsible only for the nursing care of the sick.

4. The hospital stands ready at all times to cooperate as far as possible with the attending physician in all efforts to advance medical science.

In conclusion I would summarize as follows:

1. The hospital is a community problem because it is supported by the community.

2. The existence of the community-supported hospital can only be justified when it is accessible to every citizen through his physician.

3. The patient in the hospital belongs to his physician.

4. The hospital is responsible for the housing and nursing care of the patient.

5. The physician is responsible for the medical care of the patient.

6. The hospital can best perform its function independent of control by the physicians whom it serves.

7. The medical profession can best care for their patients independent of control by the hospital which should serve them.

8. The Medical Staff of the hospital tends to divide and complicate hospital authority.

9. As the hospital staff becomes more autocratic the number of patients in the hospital becomes less.

10. The sections of the country with closed hospital staffs have fewer hospitals to the number of population than sections of the country with open hospital staffs. Communities with hospital staffs have both smaller hospitals and less hospital facilities than communities without hospital staffs.

11. The adoption of the Minimum Standard of the American College of Surgeons will eventually result in autocratic hospital staff control of the hospitals of the country. Hospital staff control will deprive 85% of the physicians of their hospital practice and 85% of the population of their hospital privileges.

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THE APPLICATION OF BACTERIOPHAGE TO PUBLIC HEALTH

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Some years ago Hankin observed that the water of the Ganges and Jumna Rivers in India have marked bactericidal action for bacteria in general and for cholera vibrio in particular. The water of Jumna river contains, at the city of Agra, more than 1000 bacteria per cc. Five kilometers below this it contains only 90 to 100 bacteria per cc. When this water is passed through a Berkefeld filter it shows a marked bactericidal action for the cholera organisms, in four hours destroying all organisms when a little of the water is placed in a broth culture of cholera vibrio. When this water is boiled it loses its bactericidal action and cholera vibrio grow well, as they also do in water taken from wells in the vicinity of the rivers. Hankin had no adequate explanation of the peculiar phenomenon.

In 1916, Twort was attempting to isolate filterable viruses from nature which might be grown on ordinary culture media. In this he was unsuccessful. In his work on calf vacinnia (smallpox vaccine) he noted that cultures of micrococci growing from the glycerinated vaccine became glassy and transparent and could not be subcultured. By transferring a little of the glassy material to new tubes of micrococci, these also became dissolved. Action was strongest with young cultures and could not be demonstrated in very old cultures. The lytic principle passes through the finest clay filters, but would not grow of itself on any culture media. Twort was not certain whether the lytic action was due to a minute parasitic organism, an amoeba or an anzyme secreted by the micrococcus.

The investigator who has taken up the work of these two pioneers and made a most careful study of it is d'Herelle. It is his theory that there is one parasite for all bacteria which adapts itself to the various kinds of

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organisms. These parasites pass through the finest clay filters, but can be cultivated only in the presence of the bacteria. Bordet states the phenomena is a defensive process due to the leucocytes which give to the organisms an hereditary property of producing a lytic ferment. The only difference between these two theories is whether the lytic ferment is produced by an ultra-microscopic virus or whether it is produced by the bacteria themselves. Kabeshino claims that lysis is due to a prodiastase present in the bacterial cell which is activated by a catalysor contained in filtrates of intestinal contents; in other words, that lysis is due to a ferment from the tissues. Salibeni has found a myxamoeba in lytic filtrates. Elivia and Pozerski described the destruction of Shiga bacillus by salts of quinine. Whatever the nature of the principle, however, it is certain that in persons convalescing from disease, notably typhoid fever, bacilliary dysentery and cholera, a substance is present in the stools that will dissolve the bacteria from which the patient is suffering when these two are placed together.

As was stated before, it is impossible to grow this lytic principle, whatever it may be, except in the presence of young cultures of bacteria, but bacteria free cultures will remain active for as long as six months. Anaerobiosis does not favor the lytic action. The material can be passed from tube to tube of bacteria an indefinite number of times and will remain active in clear filtrates for six months. In centrifuged specimens of filtrates, nothing can be demonstrated by staining the sediment. However, when a little of the sediment is examined with the ultra microscope, very fine points of light are seen dancing in the medium. d'Herrelle claims these are the organisms in question. The principle reacts to physical and chemical agents very much as do bacteria, being destroyed by antiseptics and heat and being quite susceptible to acids and alkalies, preferring a slightly alkaline medium for growth.

The lytic action of this ultra microscopic organism, if such it is, can well be demonstrated in a test tube experi-

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ment. If to young cultures of Shiga bacillus on slant agar or in broth, some of the lytic principle is added, all of the bacteria disappear and the medium becomes perfectly clear. After a short time, however, a growth reappears, but this is not typical of the organism in question. Grattia designates these organisms by the letter R for resistant, and those dissolved by S for susceptible organisms. The resistant organisms can be transferred from generation to generation but are not typical either in morphological or cultural characteristics. Old and dry cultures of bacteria contain more resistant organisms than young cultures.

The lytic principle has been found so far only in intestinal contents with the exception of the experiments of Twort where he found it in vaccine virus. d'Herrelle is of the opinion that all normal persons harbor the principle, although in some persons it may be weak and it must be activated for demonstration. A person does not become ill upon infection if he has sufficient bacteriophage in his system. If the bacteriophage is weak he may develop signs of the disease but recovers after the lytic principle becomes activated. If the lytic principle does not become activated or if the resistant strain of organism develops, the patient may not recover. Possibly the production of organisms resistant to the bacteriophage is responsible for relapses in typhoid fever. d'Herrelle claims that the only persons from whom he could not obtain bacteriophage filtrates were those destined to die. In the lower animals, as in men, the bacteriophage is easy to demonstrate. It has been found in horses, chickens, calves, buffaloes, rabbits and other animals. Very probably it is widely distributed in nature.

The bacteria susceptible to lysis by bacteriophage are mostly those from the intestinal tract, though others have been described. The dysentery bacilli,—Shiga, Hiss and Flexner,—all are very susceptible. The typhoid group including the paratyphoid and the colon group are likewise easily lysed. Bacillus proteus, Staphlococcus Bacillus subtilus, the cholera organisms, and Bacillus pestis have been made the subject of study. The diph-

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theria bacillus has not received very much attention, although d'Herrelle found in the manure of diphtheria antitoxin horses a substance which would dissolve the diphtheria bacillus. Among the lower animals, for the organisms of fowl typhoid, hemorrhagic septicemia and plague of the rat, a lytic substance was present in the intestines. As d'Herrelle says, probably the parasite is the same for all organisms, but becomes adapted to specific organisms according to the conditions.

The most interesting results obtained with bacteriophage from a public health standpoint are the inoculation experiments of d'Herrelle. In an epidemic of avian typhoid which was scattered over 25 poultry farms, from 20 to 50 percent of the fowls had died from the disease. He gave to 600 of the fowls by ingestion 1 cc. of the bacteriophage culture activated against B. gallinarium, and to 1500 more 0.5 cc. of the same culture subcutaneously. Not one of the fowls on the 25 farms which had received the bacteriophage died, although the epidemic continued to rage on other poultry farms in the vicinity. In Indo-China hemorrhagic septicema among the buffaloes is an exceedingly fatal disease. By injecting into 100 buffaloes 0.25 cc. of bacteriophage principle, d'Herrelle immunized the animals to such an extent that they received without harm 1000 fatal doses of the pathogenic bacteria necessary to kill buffaloes under ordinary conditions. The blood of these immunized animals conferred immunity upon other animals when infected. Rabbits, which are very susceptible to the toxin of bacilliary dysentery, were rendered immune by the subcutaneous injection of a small amount of bacteriophage. In seven cases of dysentery in man, the injection of 1 cc. of bacteriophage was followed in from 24 to 36 hours by the disappearance of blood and bacillus from the stools.

From these results it would seem that it would be a simple matter to immunize our population against all intestinal diseases, by simply injecting a small amount of bacteriophage. In case a person contracted a disease, he could be cured by injection of bacteriophage. Probably the problem will not be solved so easily. d'Herrelle

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warns against repeated doses of bacteriophage since these make animals hyper-susceptible and a greatly reduced amount of infection is required to produce death.

Bacteriophage is interesting from a public health standpoint. While it is not permissible to theorize on a subject which can be settled only by scientific research, yet there are some matters of particular interest to which I wish to call attention. Do persons become ill because of lack of bacteriophage and recover when this principle is activated or when it is supplied artificially, as by ingestion? Is the higher mortality among the primitive races accounted for, in tuberculosis for instance, because of the lack of bacteriophage against tuberculosis? And is the greater resistance of the so-called civilized races to tuberculosis due to the fact that the population in general has imbibed more or less freely from each other of bacteriophage principles? In the self purification of streams polluted by sewage, does bacteriophage have any part in destroying the intestinal organisms? From the observations of Hankin in India, it would appear that this is so. These are only a few of the problems of public health which are before us to be worked out.

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THE SCHICK TEST IN DIPHTHERIA AND TOXIN ANTI-TOXIN IMMUNIZATION.

C. A. Earle, M. D., DesPlaines

More is known to-day of the cause, manifestations and cure of diphtheria than perhaps any other disease.

Science knows but one remedy for the cure of an attack of diphtheria, viz. large doses of diphtheritic antitoxin given early in the disease. This remedy has reduced the mortality 50%, yet diphtheria is still the most fatal of the infectious diseases of children, and its prevalence is absolutely undiminished. 700 to 800 children die of diphtheria in Chicago every year. Too often the child is overpowered by the diphtheritic poison before antitoxin is given, and disaster is unobstructed. It is believed that with our present methods of prevention and cure the mortality and incidence of this disease can not be further lessened.

The modus operandi of an attack of diphtheria is as follows: Virulent diphtheria bacilli by personal contact with a case of diphtheria or with a carrier are implanted upon the mucous membrane of a child's throat. They begin to grow in the throat like the mold on a contaminated glass of jelly. These germs do not enter the child's tissues or blood. They start at once to manufacture one of the most deadly poisons known, viz., diphtheritic toxin. This diphtheritic toxin enters the blood stream and if unneutralized by antitoxin produces its characteristic destructive and paralyzing effects.

If, however, the child shortly before contact had received a sufficient amount of antitoxin, or if the child is naturally immune to diphtheria, or if active immunity had been induced by the injection of T. A. mixtures to which I shall refer presently, this deadly toxin is neutralized and diphtheria does not result. The germs themselves prowl around the child's throat, get discouraged, and in course of time varying from one week to several months leave for more fertile fields or disintegrate.

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It is interesting to know that approximately only 50% of children of school age are susceptible to diphtheria. In other words, about one-half of the children are naturally immune to this disease. They would not get the disease even upon the closest contact with a case of diphtheria. This is due to the fact that there exists in the blood of such children at least 1/30 of a unit of diphtheritic antitoxin to each cc. of blood. The amount of antitoxin in a child's blood can be as accurately determined as the composition of the rocks or the interplanetary distances. This natural immunity is technically called active immunity and is believed to be permanent; that is, if after the first year of life the child is immune, he will always be immune. Carefully distinguish between this active immunity and what is called passive immunity, because I shall use these terms later. Passive immunity is the immunity occasioned by the transitory presence in the blood of sufficient antitoxin to prevent or cure diphtheria. This condition of immunity may be brought about by the direct injection of diphtheritic antitoxin into the child's blood or tissues. In practice, 1000 or 1500 units of antitoxin are injected into a child who has been exposed to diphtheria to prevent his getting it. The immunity so conferred is passive immunity. It is short lived, lasting about four weeks, after which the child is as susceptible as ever and perhaps more susceptible.

It will be conceded readily that it is important to determine if possible by some safe simple test a child's status with reference to diphtheria. If he is permanently immune, he will not get diphtheria nor will he need the immunizing dose of antitoxin if exposed to diphtheria. Sore throat of some kind is one of the most frequent diseases of childhood; comparatively few cases are true diphtheria but every case is potentially diphtheria, hence thousands of bottles of diphtheritic antitoxin are needlessly given every year in this state.

Until nine years ago the only way to determine whether a child was susceptible or not was by a tedious process of blood examination. In 1913, an Austrian physician by the name of Schick devised a simple skin

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test that is almost infallible. It consists in injecting into the skin of the arm or any where a few drops of a high dilution of diphtheritic toxin. If in 3 or 4 days a small area of redness develops which gradually disappears, leaving a discolored scaly spot, the child is susceptible. If nothing results from this intra cutaneous injection, the child is naturally immune and probably for life. I have given nearly 8000 of these tests. It is almost painless and absolutely devoid of any danger whatever. Having determined by the Schick test that about one-half of the school children might get diphtheria if exposed to it, no vivid imagination is required to understand the desirability of immunizing, if possible, those that are susceptible. To me, how a great discovery is made is as interesting as the discovery itself. In this instance, as often happens, chance is entitled to almost as much credit as science in elaborating this most wonderful discovery. Again and again opportunity knocked at the Laboratory door of science, and offered a way and means of preventing this dreadful disease. As I shall presently indicate, the solution of this problem of active immunization in diphtheria was going on right under the eyes of every antitoxin laboratory worker in Christendom long before they knew it. I have thought sometimes that research workers, elated with their victory over laboratory diphtheria, have been slow to realize the importance of discovering some way of permanently immunizing the oncoming hoards of susceptible children. Behring himself sooner or later saw the necessity of active immunization because the protection afforded by immunizing doses of antitoxin was short lived. This often necessitated repeated doses of antitoxin which sometimes resulted in serious anaphylactic reaction. It is 14 years since Smith suggested, but 9 years since Behring, Park and others first used TA mixtures to actively immunize children. Of course this time is too short for us to be dogmatic, but the results thus far attained justify us in asking for the widest possible use of such mixtures if we are to limit further the ravages of this disease. Time will, I believe, demonstrate that few discoveries in medical science have been made which offer greater po-

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tential possibilities for the prevention of a serious disease than the elaboration of the toxin-antitoxin mixtures for the prevention of diphtheria.

While Behring christened the mixtures which he used with the name TA and was the first to employ them for immunization in humankind, he was in no wise the first to suggest their use. Apparently Behring's TA mixtures were born with teeth and fully armed to fight diphtheria, for nowhere does he state how and when he conceived the idea nor does he give the relative proportions of the toxin and antitoxin in his mixtures. The evolution of a great discovery is usually a tortuous record of blunders, stumbling, infinite patience and industry, keen observation, half-baked conclusions and fearlessness in breaking away from traditional lines of thought. This is the history as I see it of the development of the TA mixture. Of those who contributed to the solution of the mystery of active immunization in diphtheria, one name so far outdistances all others that what I shall say is taken largely from his reports. That name is Theobald Smith.*

The first step toward active immunization against diphtheria was made in 1895, when Wernicke reported that the offspring of the guinea pigs which had previously been treated with toxin and antitoxin possessed increased resistance to diphtheria toxin. He also showed that the male parent guinea pig in no way influenced the immunity of the young. These important observations passed unnoticed for a number of years. In 1902, Park immunized horses, goats and guinea pigs by mixtures of diphtheria toxin and antitoxin. As a matter of fact, he and others had actively immunized horses long before this, because in the treatment of horses to be bled for furnishing diphtheria antitoxin they had almost from the first learned that by injecting antitoxin with initial dose of toxin, stronger doses of toxin could be used, resulting in a greater and more rapid formation of antitoxin in the animal's blood.

None at this time seemed to realize the possibilities of all they were doing. They were interested only in the commercial production of a potent antitoxin.

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Three years later, in 1905, Theobald Smith reported an interesting observation. Guinea pigs have always been used to test and standardize diphtheria toxin and antitoxin. Bearing this in mind, it can be understood readily how vital it is that the susceptibility of the animals used in these tests should vary as little as possible. Smith noticed that guinea pigs bought in the open market were less resistant to toxin than those he raised in his laboratory. He also noticed that the resistance of his own animals varied. He at first attributed these variations to individual susceptibility or to differences in food and environment. For the time being he ruled out any preliminary treatment of the animals as a cause of variations in their immunity. Continued irregularities in his tests seemed to have disturbed Smith's mind, for he studied more intensely and carefully the effect of preliminary treatment of the female parent with reference to the antitoxin content of the blood of the offspring. Two years later, in 1907, he reported that preliminary treatment of female guinea pigs with TA mixtures not only immunized them, but the offspring of these treated mothers were passively immunized. In addition he demonstrated conclusively that this passive immunity of the offspring is a correct measure of the active immunity of the mother guinea pig. This discovery was exceedingly important, for by testing the successive litters of guinea pigs he was enabled to watch the persistance of the active immunity in the parent guinea pig. Behring had maintained that the immunity of the animal parents had absolutely no influence on the susceptibility of their offspring. This fiat of Behring undoubtedly adversely influenced research workers the world over.

Smith found that this active immunity lasted for several years. He also showed in this paper of 1907 that there is apparently no relation between the severity of the reactions produced by the immunizing agents used and amount of active immunity resulting. Animals that were just able to survive a most powerful dose of toxin did not thereby possess any immunity, while the injection of a single dose of a mixture of toxin and antitoxin that caused no local or general disturbance did confer a

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high degree of lasting immunity. It was in this paper that he made that memorable suggestion that human kind might thus be actively immunized by neutral mixtures of toxin and antitoxin.

This idea was so revolutionary and contrary to accepted theories that it attracted no attention. Two years later, in 1909, this medical Leverrier, with the courage of his convictions, again pointed the way to human immunization. Three years more followed and still no one arose to follow Smith's prophetic finger. It was not until 1912 and 1913 that Behring himself, who had evidently experienced a change of heart, without mentioning Smith's name, reported successful active immunization with TA mixtures. The fear of the known effects of diphtheria toxin on the nerves and heart, together with Behring's dictum mentioned before in this paper, undoubtedly deterred research workers and clinicians from the earlier use of TA mixtures. It seems to me no one can read Smith's reports and not be convinced that TA mixtures do produce a lasting immunity in these animals.

Experimentation has abundantly proved that the tests, manifestations of the disease, immunity and susceptibility observed in the guinea pig are exactly the same in human kind. TA mixture, as the name indicates, is a simple mixture of the diphtheria toxin with antitoxin in which the toxin is not quite neutralized. It is given subcutanously in three doses of 1 cc. each at intervals of seven days. Immunity develops slowly, often not reaching its maximum until five or six months have elapsed. Experience shows that about ninety percent of the children receiving the three doses have been rendered immune during the whole period of observation, namely three to seven years. You will hear undoubtedly of the danger of giving these TA mixtures. In fact several deaths resulted in Dallas, Tex., because a mistake was made in the laboratory in the preparation of the mixture. I have given about 3500 injections in children without an unpleasant result. Park and Zingher in New York have given thousands and thousands of these injections without a death or loss of an arm. I had one

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unpleasant result from an injection I gave a nurse. Recovery was not complete for four or five months.

SUMMARY

1. Experimental evidence is unimpeachable that TA mixtures do produce lasting immunity to diphtheria in lower animals. Clinical results are accumulating which show that similar active immunization can be produced in human kind. In my own experience the persistant use of such mixture has immunized 98 to 99 percent for a period up to three and one-half years.

2. The Schick test made with a potent toxin carefully performed and properly interpreted is almost an infallible indication of susceptibility or immunity to diphtheria.

3. All children above one year of age should be given a Schick test to determine their status with reference to diphtheria and also whether they are to be given subsequently TA or not, just as a person should know his history with reference to other infectious diseases.

4. All school children should be required to present to the school authorities a certificate showing at least the results of a Schick test and if possible active immunization with the TA mixture.

5. On account of the severe reaction following the use of TA mixtures in adults and because of the relative immunity of adults, only nurses and doctors given strong Schick reactions should be given TA.

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FOCAL INFECTIONS FROM THE TEETH.

FRED S. O'HARA, M. D., D. D. S., SPRINGFIELD

"Uneasy lies the head that wears the crown" is an old saying; and in the light of our present knowledge of teeth and focal infections, the author of the above phrase was surely referring to the teeth, rather than the head, when he mentioned crowns.

A properly functionating tooth is a live member of the body, with its own blood supply and its own nerves. Kill the nerve of the tooth and the blood supply dries up; the dentist "opens up the root canal" and drains the tooth of debris and pus. Unfortunately, the tendency of the poisonous material is to try to escape through the *apex* of the tooth instead of through the opening that the dentist has prepared, which is usually plugged up with food particles or "temporary stopping." At the apex of the tooth, these germs that have been pushed up or have gravitated up (or down) to the apex of the tooth root set up shop and await opportunity for some nice clean "dirty work". It is useless for me to endeavor to explain all the processes of infection and of focal infection to an audience who need it about as badly as I need a course upon the geology of the Rock River. My message is that of warning you against the dangers of devitalized teeth and the resultant focal infections.

I assert that appendicitis, heart lesions, ulcers in the intestinal canal, kidney lesions, various kinds of joint inflammations and a host of other diseases may result from the germs that keep shop at the apices of devitalized teeth. If you do not believe me, ask your old-tried-and-true friend, your family doctor, and unless he is a product of the pliocene period, I am sure that he will agree with me.

Ask my old friends and colleagues, Drs. Bain and Hull, sitting over there listening to me, how they would like to harbor a culture of streptococcus viridans (germs) and they will answer up very promptly that they are strongly "agin-it". Yet, each and every time a tooth is

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devitalized the end result is some form of apical infection that may lie dormant throughout life, or may destroy life itself. Do not think that because your devitalized teeth have never caused you "rheumatism" that they cannot do it. Early in the war the British thought the submarine was only a joke—but they learned better. Have the respect for your devitalized teeth that was finally accorded the submarine. The analogy is not so far fetched. The sub slips in unseen and deals its blow; the apices of the teeth are unseen save by the x-ray, but they are as potent for harm as you can possibly imagine.

Now, why is it that hundreds, yea, millions of devitalized teeth have (apparently) gone through life without causing harm? Write this down upon your mental slate "Vis Medicatrix Naturae". But for this prescription the human race would have died out with the birth of the first baby. (Let us see, was it "Adam Junior" or "Cain?" Some of you ought to be able to tell.)

The antitoxins, or anti-poisons, manufactured by the system itself hold the virulent apical germs in check; otherwise they would score a far greater batting average. But, at that, the triumvirate of the "Three T's" (teeth, tonsils and toxaemia) cause about sixty percent of the sicknesses of mankind (and womankind).

In a New Jersey Hospital for the insane, scientific experiments concerning the "three T's" were carried out, with a conclusion that almost one half of the mentally unbalanced could be restored to reason by the proper attention to the "three T's".

It were possible to cite instance after instance, wherein the sickness of the individual could be directly traced to the teeth roots (apices), but it would be a great waste of white paper without consequent gain in argument. Those who doubt the deductions of such men as Rosenow, Norvitzky, Arthur Smith, and many others, probably doubt the existance of the giraffe, and new varieties of Heinz's pickles.

To doubt is a human privilege. An iconoclastic dentist has written a wonderfully funny pamphlet suggest-

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ing the removal of ALL TEETH as soon as they are erupted, thereby making an "100% Edentulous Society" and thus avoid all the diseases caused by teeth abscesses.

My answer to the pamphlet has been formulated by William Cowper Brann. "Assail a fool with reason and he answers you with calumny".

Deriding modern scientific procedure is not going to cause it to retreat within its shell for a hundred years. A couple of thousand years ago, it was great sport to feed Christians to lions, to make a holiday in Rome; but it did not kill out the Christian religion in Rome. It made it a poor hazard so far as life insurance was concerned, but it was nowise worse than the troubles resulting from focal infections of today. Roosevelt gave his life (unintentionally) rather than the offending tooth. It is just possible that had ex-Kaiser William lost his teeth early in the game, he might not have been so anxious for a bite at Belgium. But we are digressing—we are upon the subject of focal infections with especial reference to the teeth. I cannot tell you how to stop those which have already occurred save by extraction of the offending tooth, but to prevent apical abscesses it were well to

1. Have your teeth examined by a competent dentist at least once a year.
2. Time is proving that artificial dentures are safer and more sanitary than bridges and crowns.
3. A tooth that aches or has ached is safest when removed from your mouth.
4. Be suspicious of any dental work that necessitates the devitalization of a tooth (killing the nerve).

The real answer to the matter lies in the mouths of the school child of grammar school age. In Boston they have been doing heroic work among the school children, and results are astounding. The adult mouth cannot be reformed. Those teeth you have already had restored are a menace to your health. Were they mine, they would be OUT.

Difference of opinion made horse racing possible, and your ideas concerning teeth may be different from mine.

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Let me impress you that my ideas as I have expounded them to you this afternoon are the ideas of Rosenow, Murphy, Norvitzky, Smith, and a host of others who have investigated the subject from a wholly neutral standpoint. I regret that I have not the "silver tongue" of Bryan, that I might plead the cause of a healthy mouth in a way that would send a string of you to the dentists this very afternoon.

But whatever idea you may carry away from this discourse please—oh—please see that this accompanies you wherever you may go:

"DON'T LET YOUR TEETH ACHE".

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A STUDY OF THE EFFECTS OF RADIUM AND X-RAY TREATMENT OF MYELOGENOUS LEUKEMIA *

GLEN WEVER, ILLINOIS COLLEGE, JACKSONVILLE

Abstract—

Myelogenous Leukemia is a rare, and to the extent of present knowledge, incurable blood disease. The case here observed presents a number of distinctive features, among which is the relatively small number of white blood corpuscles when considered in comparison with most cases of the disease. Three ray treatments, two of Radium and one of X-Ray, gave results from which it is difficult, as well as inadvisable, to draw definite conclusions. The progress of the disease during the period of observation, November, 1919, to April, 1920, the various effects of the ray treatments upon the elements of the blood stream, and other features of interest and significance are shown by means of graphs and charts.

The work with which this paper deals was the study of a case of *myelogenous leukemia* by means of differential blood counts. A brief clinical history of the case is taken from the Sanatorium records.

The patient was a man 59 years of age, engaged in farming. He sought medical attention on November 27, 1919, at which time he reported the previous duration of the disease to be 18 months. He complained of general weakness, loss of weight, aches in the limbs, headache, flashes before the eyes, feeling of distress, and fullness in the epigastrium. Examination disclosed subnormal nutrition, flaccidity of the muscles, and marked increase in the size of the spleen. The hemoglobin test gave a result of 75%. The case was diagnosed as *myelogenous leukemia.*

The period observed is from November, 1919, until April, 1920. During that time three Ray treatments were given. The first, about December 6, consisted of 5,000 milligram hours of Radium treatment. On December 5,

* The author wishes to express his indebtedness to Dr. F. G. Norbury, of Jacksonville, for providing the opportunity and the directions that made this work possible.

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before treatment, the white count was reported as 85,000; on December 15, after treatment, it was 28,000. Also, both spleen and liver had decreased in size. The lower border of the spleen maintained about the same position, but the upper border showed a marked retraction. The patient grew cheerful and hopeful of improvement. On January 10, 1920, a second Radium treatment was given. On January 6 the white count was reported as 33,000; on January 15, after this treatment, it was 47,000. On January 24 an X-Ray treatment was administered. Later X-Ray treatments beyond the extension of this study were made. The patient died in October, 1920, making the total duration of the disease 2 years, 5 months.

In the blood picture the most striking feature was, of course, the large number of white corpuscles, and especially the presence of a large percentage of myelocytes of the neutrophile variety. *Anemia*—decrease in the number of red corpuscles, was also present. A large number of nucleated red cells was found. Many of the red cells, as well as the white, showed karyokinetic figures. Extruded nuclei, blood platelets, and fragmented cells were prominent. *Anisocytosis, Poikilocytosis,* and crenation were present in variable extent throughout the period of observation. The hemoglobin was diminished in approximate proportion to the red blood corpuscles, and stood usually at 75%. A number of rare pathological forms were noticed. One *megakaryocyte* was discovered.

The progress of the disease can best be observed by means of the accompanying charts and graphs. Chart I shows the complete observation (with exception of certain white counts in the earlier part of the treatment for which slides were not available. These counts are taken from clinical reports and included in the graphs). For each day for which blood slides were available a differential count was made of 200 white cells. The tabulation shows the percentage of Polymorphonuclear neutrophiles, Polymorphonuclear eosinophiles, Polymorphonuclear basophiles, Lymphocytes, Mononuclear leucocytes, neutrophilic Myelocytes, eosinophilic Myelocytes, and basophilic Myelocytes, respectively. During the

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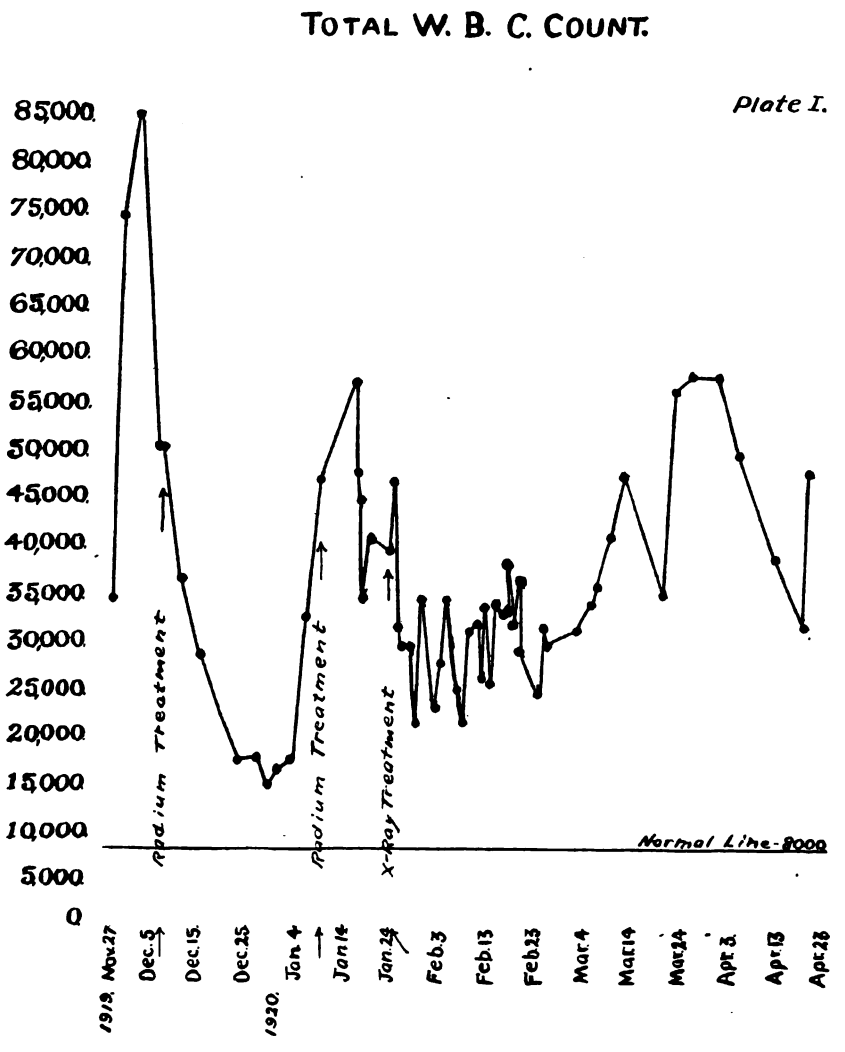

counting of 200 white cells, the actual number of nucleated red cells appearing in the field was recorded. These are grouped as normoblasts, megaloblasts, and microcytes, respectively. The chart shows in the first three columns the hemoglobin tests, the number of white blood corpuscles in 1 cubic millimeter of blood, and the number of red blood cells per cubic millimeter.

The data of the second chart is computed from that of the first. Here the actual number per cubic millimeter of

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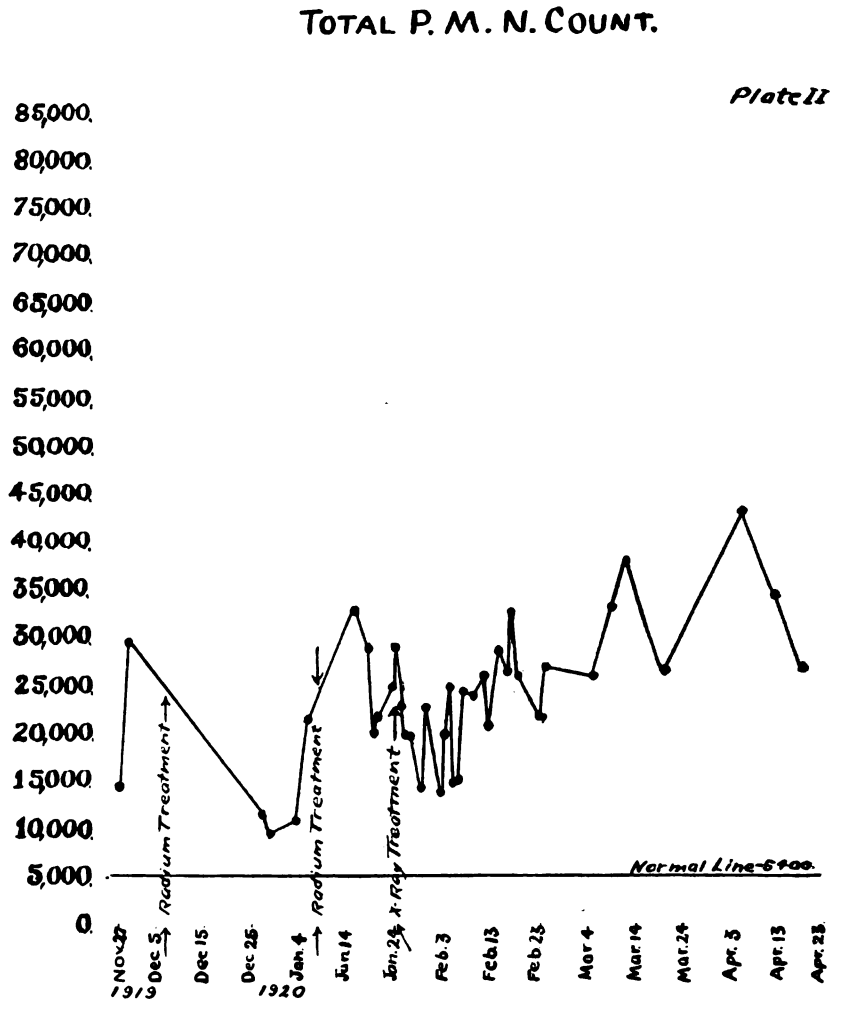

polymorphonuclear neutrophiles, neutrophilic myelocytes, and remaining white cells is shown. This chart is the basis for the first four graphs that follow.

The first graph (Plate I) shows the Total White Blood Count. The variability of the number of white blood cells, a characteristic of this disease, is easily seen, especially in the period of most intensive observation, January 25 to February 18. The ray treatments are indicated by the arrows. It will be noticed that after each

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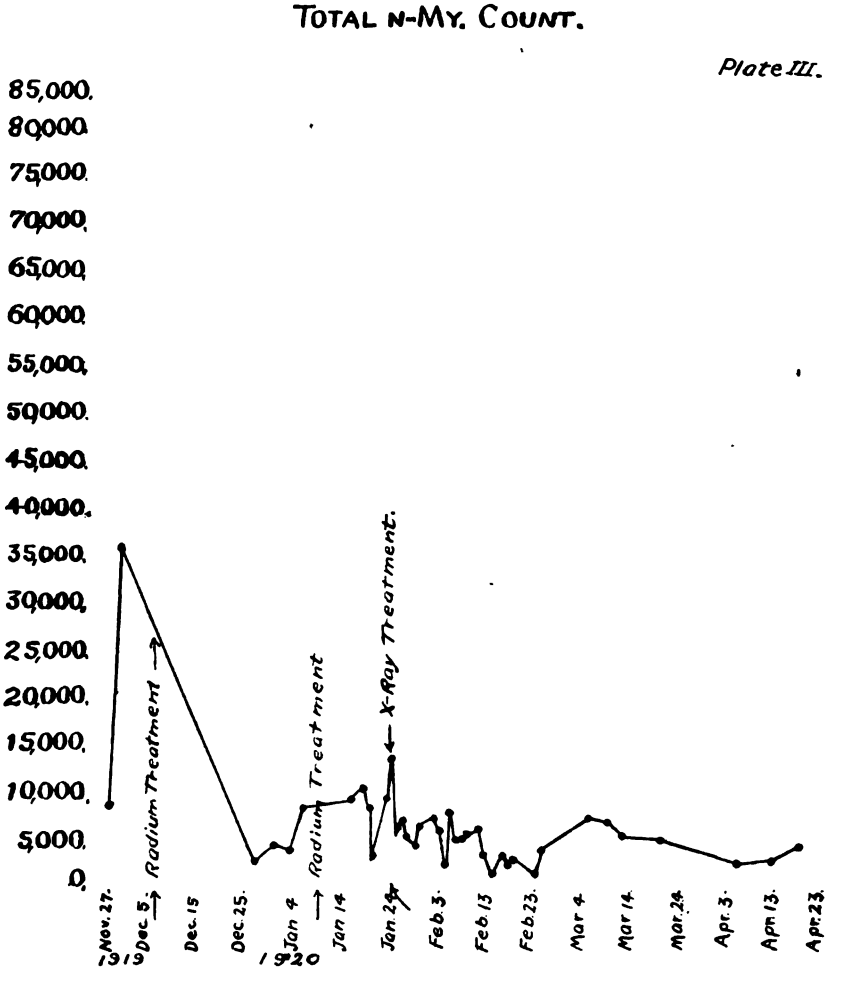

treatment the total white count fell perceptibly only to rise again.

The second graph (Plate II) shows the total per cubic millimeter of polymorphonuclear neutrophiles. Here also the count is seen to fall after ray treatment.

The third graph shows the total per cubic millimeter of neutrophilic myelocytes. The influence of the ray treatment is more uncertain, though the general trend is downward.

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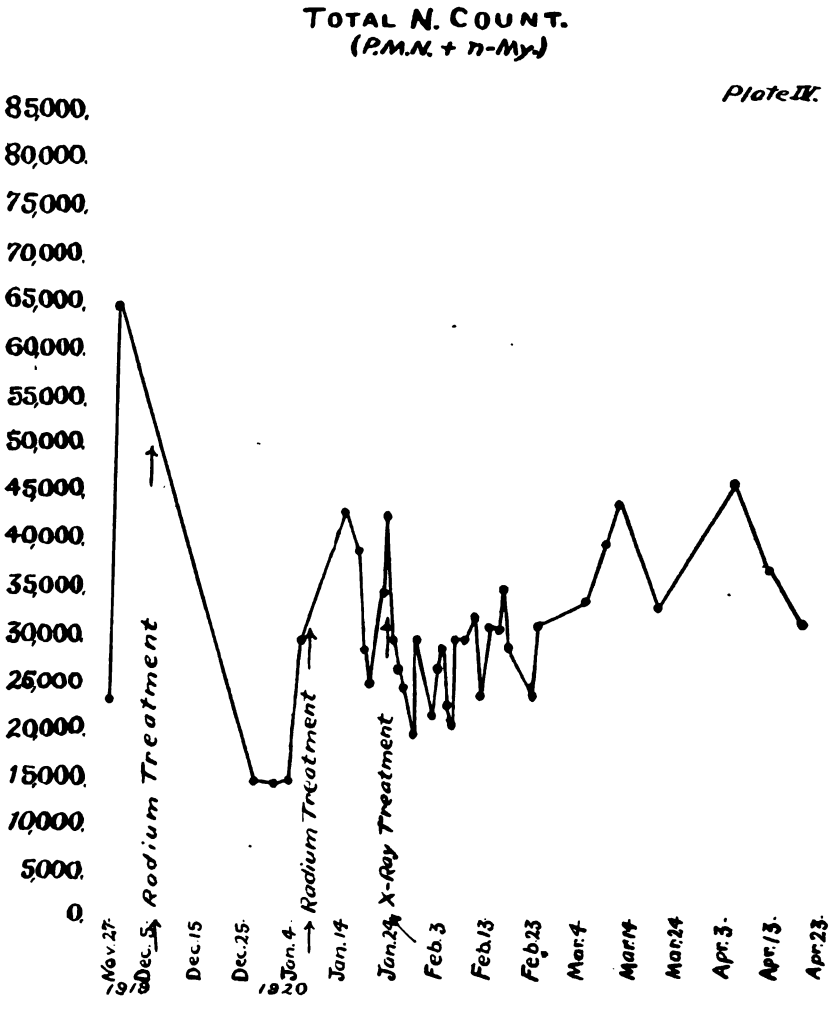

Plate IV portrays all neutrophilic cells—the polymorphonuclear neutrophiles and neutrophilic myelocytes added. The general effect is the same as that noted in Plate II.

The fifth graph (Plate V) shows the count per cubic millimeter of red blood corpuscles. It will be remembered that besides leukemia, anemia was present in this case. The red blood count varied from 2,500,000 (half the normal number) to practically normal. The general

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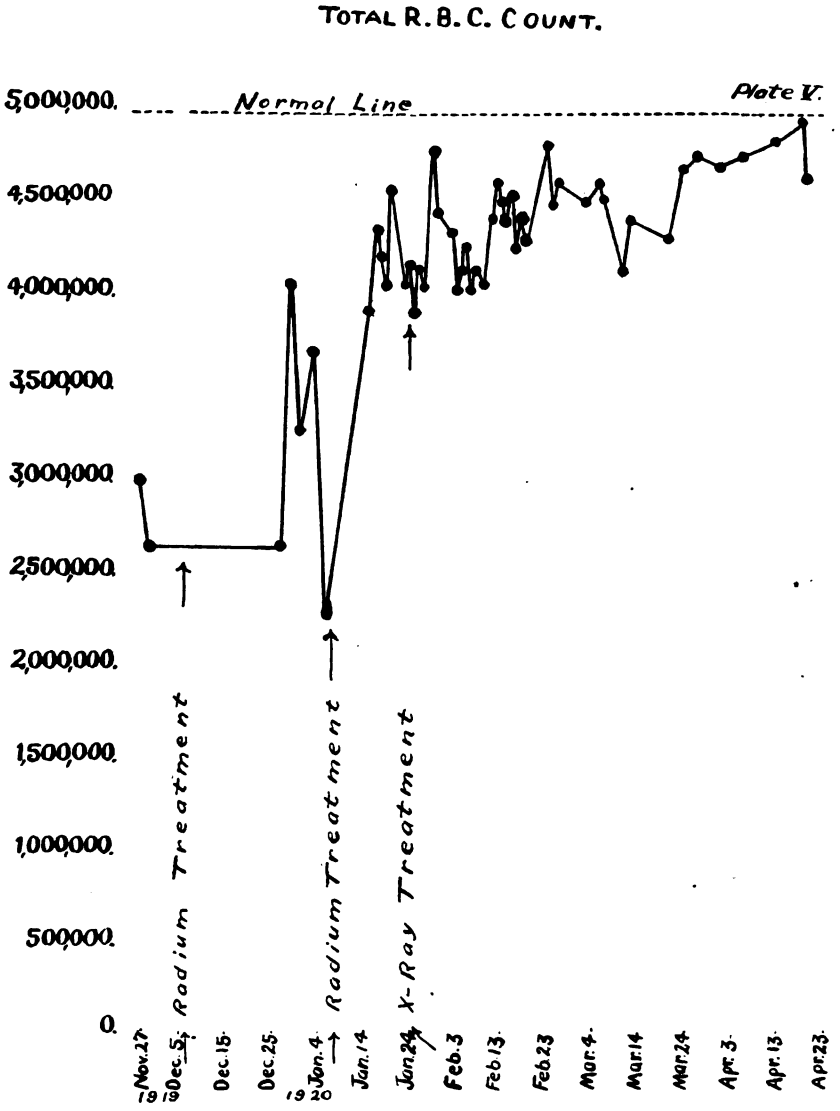

effect of the ray treatment seems to be a raising of the count. The general trend of the curve is seen to be upward.

As has been suggested, the observations here tabulated include only a fractional part of the entire course of the disease. From observation covering so brief a period of a single case it is obviously impossible to draw any definite conclusions as to the whole effects of Radium or

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X-Ray treatment of Myelogenous Leukemia. Many more cases must be subjected to exacting study before reliable conclusions can be made. Effective treatment for Myelogenous Leukemia is a problem for the future to solve.

EXPLANATION OF SYMBOLS FOR PLATES AND CHARTS.

Hb	Hemoglobin test.
W. B. C.	White Blood Corpuscles.
R. B. C.	Red Blood Corpuscles.
P. M. N.	Polymorphonuclear neutrophiles.
P. M. E.	Polymorphonuclear eosinophiles.
P. M. B.	Polymorphonuclear basophiles.
L	Lymphocytes.
M	Mononuclear leucocytes and Transitionals.
n-My	neutrophilic Myelocytes.
e-My	eosinophilic Myelocytes.
b-My	basophilic Myelocytes.
No	Normoblasts.
Mg	Megaloblasts.
Mi	Microcytes.
Total N.	Total number of neutrophilic cells—P. M. N. + n-My.

See Charts I and II on the following pages.

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CHART I.

A case of Myelogenous Leukemia.				— W. B. C. — Differential Count.							
Date.	Hb.	W. B. C.	R. B. C.	PMN	PME	PMB	L	M	n-My	e-My	b-My
1919											
11-27	75	33,900	2,960,000	42	2	.....	25	5	26	.....	.....
11-28	.....	.....	.....	43.2	0.2	1.5	8.5	9.8	34.3	.....	2.5
11-29	.....	74,400	2,600,000	39	2	2	5	3	48	.....	.....
12-27	.....	17,000	2,600,000	69	.....	.....	6	6	17	.....	.....
12-29	.....	14,600	4,080,000	.....	.....	.....	.....	.....	.....	.....	.....
12-31	.....	16,200	3,232,000	60	.....	.....	8	2	29	.....	1
1920											
1-3	.....	17,400	3,664,000	60	.....	.....	12	5	23	.....	0.5
1-6	58	33,000	2,240,000	64	.....	.....	6	2	25	0.5	2
1-15	.....	47,000	3,892,000	69	.....	0.5	5	2	21	1.5	1
1-17	.....	56,800	4,304,000	.....	.....	.....	.....	.....	.....	.....	.....
1-18	75	44,400	4,160,000	64	0.5	0.5	10	1	23.5	.....	0.5
1-19	.....	34,000	4,048,000	58	.....	0.5	9	4	24.5	2.5	1.5
1-20	.....	40,400	4,528,000	52.5	2	1.5	5.5	3	33.5	1	1
1-23	.....	39,200	4,068,000	62.5	1	.....	7	4	25.5	.....	.....
1-24	.....	46,600	4,120,000	62	.....	.....	6.5	3	28.5	.....	.....
1-25	.....	31,000	3,860,000	72	.....	.....	3	3.5	21.5	.....	.....
1-26	.....	29,200	4,128,000	67	3	.....	2	4	23	1	.....
1-27	.....	29,200	4,040,000	66	2.5	0.5	5	7.5	18.5	.....	0.5
1-29	.....	21,000	4,784,000	68	0.5	0.5	4	3	22.5	1	0.5
1-30	.....	34,200	4,416,000	66	.....	0.5	3.5	9.5	19.5	.....	1
2-2	.....	22,800	4,320,000	60.5	1.5	.....	.....	5	32	1	1
2-3	.....	27,600	4,028,000	71	4	.....	.....	3.5	21.5	.....	.....
2.4	.....	34,000	4,112,000	73	2	0.5	4	10	10.5	.....	.....
2-5	.....	25,400	4,232,000	61	0.5	0.5	5	.....	32	0.5	0.5
2-6	.....	21,400	4,007,000	71	0.5	.....	1	1.5	25.5	.....	0.5
2-7	.....	30,400	4,136,000	79	1	1	1	1	16.5	.....	0.5
2-9	.....	31,200	4,056,000	76.5	1	1	1	2.5	16.5	.....	1.5
2-10	.....	25,600	.....	.....	.....	.....	.....	.....	.....	.....	.....
2-11	.....	33,000	4,384,000	78.5	0.5	0.5	.....	2.5	18	.....	.....
2-12	.....	25,000	4,570,000	81	1.5	0.5	1	1.5	14	.....	1
2-13	.....	33,800	4,456,000	.....	.....	.....	.....	.....	.....	.....	.....
2-14	.....	32,800	4,360,000	86	2.5	.....	1.5	4	6	0.5	.....
2-15	.....	37,800	4,520,000	.....	.....	.....	.....	.....	.....	.....	.....
2-16	.....	31,200	4,232,000	84	0.5	0.5	.....	2	12.5	0.5	.....
2-17	.....	36,000	4,432,000	90	.....	.....	0.5	3	6.5	.....	.....
2-18	.....	28,800	4,264,000	89	.....	.....	0.5	1.5	8.5	0.5	.....
2-23	.....	24,400	4,776,000	89.5	.....	.....	1	1	7.5	0.5	.....
2-24	.....	31,000	4,464,000	85.5	.....	.....	0.5	.....	14	.....	.....
2-25	.....	29,200	4,632,000	.....	.....	.....	.....	.....	.....	.....	.....
3-2	.....	30,800	4,496,000	14	.....	1	.....	.....	.....	.....	.....
3-5	.....	33,600	4,576,000	76	.....	.....	0.5	1	22.5	.....	.....
3-6	.....	35,400	4,496,000	.....	.....	.....	.....	.....	.....	.....	.....
3-8	.....	.....	.....	86	1.5	0.5	.....	.....	11	.....	1
3-9	.....	40,800	4,104,000	80.5	.....	.....	0.5	0.5	17.5	.....	.....
3-10	.....	.....	.....	79.5	0.5	0.5	.....	.....	19	.....	0.5
3-12	.....	47,000	4,376,000	80	2	.....	3	3	12	0.5	.....
3-20	.....	34,600	4,288,000	78	1.5	0.5	2	0.5	15.5	0.5	1.5
3-23	.....	56,000	4,656,000	.....	.....	.....	.....	.....	.....	.....	.....
3-26	.....	57,600	4,736,000	.....	.....	.....	.....	.....	.....	.....	.....
3-31	.....	57,600	4,656,000	.....	.....	.....	.....	.....	.....	.....	.....
4-2	.....	.....	.....	89.5	1	.....	1	1.5	7	.....	.....
4-5	.....	49,200	4,736,000	87.5	2	0.5	0.5	4	5.5	.....	.....
4-12	.....	38,400	4,800,000	89	2.5	0.5	.....	0.5	7	.....	0.5
4-18	.....	31,000	4,832,000	84.5	.....	1	0.5	0.5	13.5	.....	.....
4-19	.....	47,600	4,632,000	.....	.....	.....	.....	.....	.....	.....	.....
5-8	.....	.....	.....	83.5	0.5	1	5.5	3	6	.....	0.5

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I.

— R. B. C — Actual number in 200 cells.			REMARKS.
No	Mg	Mi	
.....	.....	.....	Some Poikilocytosis..... } Taken from laboratory report,
20	23	.....	Anisocytosis..... } not counted by me.
.....	.....	.....	Radium treatment December 6.. }
6	.....	.....	Some Poikilocytosis; one megakaryocye.
.....	.....	.....	Poikilocytosis.
19	.....	.....	Poikilocytosis.
16	3	.....	Poikilocytosis.
5	.....	.....	Little Poikilocytosis; Aniso.: Mitotic Reds.
22	.....	.....	Radium treat.. 1-6 to 1-15: pronounced poik. Taken from lab. report.
.....	.....	.....	
19	.....	.....	Poikilocytosis. Crenation.
29	.....	4	Poikilocytosis. Anisocytosis. Polychromasis.
37	11	.....	Crenated red cells prominent.
19	.....	3	Anisocytosis. Poikilocytosis not prominent.
20	.....	1	Anisocytosis. Poikilocytosis not prominent. X-Ray treatment.
17	.....	5	Anisocytosis. Poik. not prominent.
33	.....	6	Anisocytosis. Poik. not prominent.
30	2	7	Anisocytosis. Poik. not prominent.
20	.....	.....	Many extruded nuclei.
6	7	.....	Anisocytosis. Poikilocytosis not prominent.
11	17	.....	Anisocytosis. Poik. not prominent.
11	11	5	Anisocytosis. Poik. not prominent.
19	6	.....	Anisocytosis. Poik. not prominent.
30	2	.....	Several extruded nuclei.
8	9	.....	Several extruded nuclei.
8	5	10	Poikilocytosis and Anisocytosis prominent.
16	6	.....	Poik. and Aniso. prominent.
.....	.....	.....	
12	20	.....	Poik. and Aniso. prominent.
8	7	.....	Poik. and Aniso. prominent.
.....	.....	.....	
21	2	.....	Little Aniso. and Poik. Several extruded nuclei.
.....	.....	.....	
7	7	1	Little Aniso. and Poik. Several extruded nuclei.
7	1	1	
1	.....	.....	Little Aniso. and Poik. Few extruded nuclei.
9	2	1	Little Aniso. and Poik. Few extruded nuclei.
12	3	1	Little Aniso. and Poik. Few extruded nuclei.
.....	.....	.....	
.....	.....	.....	
6	1	.....	Little Anis. and Poik. Few extruded nuclei.
.....	.....	.....	
4	3	.....	Little Aniso. and Poik. Very few extruded nuclei.
9	3	.....	Little Aniso. and Poik. Very few extruded nuclei.
1	5	1	Little Aniso. and Poik. Very few extruded nuclei.
12	6	4	Little Aniso. and Poik. More extruded nuclei.
12	1	25	Little Aniso. and Poik. More extruded nuclei.
.....	.....	.....	
.....	.....	.....	
.....	.....	.....	
5	.....	8	Anisocytosis. Several extruded nuclei.
21	1	9	Anisocytosis. Several extruded nuclei.
5	.....	6	Anisocytosis. Several extruded nuclei.
9	1	6	Anisocytosis. Several extruded nuclei. Poik.
.....	.....	.....	} Half of the lymphocytes are of the large variety. 2 extruded
16	1	.....	} nuclei. 1 Karyokinetic figure. Poik. and Aniso. *very* slight.

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CHART II.

ACTUAL NUMBER OF CELLS PER. CU. MM.

Date	P. M N.	n-My.	Total N.	All Other	Total WBC
1919					
11-27	14,238	8,814	23,052	10,848	33,900
11-29	29,016	35,712	64,728	9,672	74,400
12-27	11,730	2,890	14,620	2,380	17,000
12-31	9,720	4,698	14,418	1,782	16,200
1920					
1- 3	10,440	4,002	14,442	2,958	17,400
1- 6	21,120	8,250	29,370	3,630	33,000
1-15	32,430	9,870	42,300	4,700	47,000
1-18	28,416	10,434	38,850	5,550	44,400
1-19	19,720	8,330	28,050	5,950	34,000
1-20	21,210	3,534	24,744	15,656	40,400
1-23	24,500	9,996	34,496	4,704	39,200
1-24	28,892	13,281	42,173	4,427	46,600
1-25	22,320	6,665	28,985	2,015	31,000
1-26	19,564	6,716	26,280	2,920	29,200
1-27	19,272	5,402	24,674	4,526	29,200
1-29	14,280	4,725	19,005	1,995	21,000
1-30	22,572	6,669	29,241	4,959	34,200
2- 2	13,794	7,296	21,090	1,710	22,800
2- 3	19,596	5,934	26,530	1,070	27,600
2- 4	24,820	3,570	28,390	5,610	34,000
2- 5	14,884	8,008	22,892	1,508	24,400
2- 6	15,194	5,457	20,651	749	21,400
2- 7	24,016	5,016	29,032	1,369	30,400
2- 9	23,868	5,148	29,016	2,184	31,200
2-11	25,905	5,940	31,845	1,155	33,000
2-12	20,250	3,500	23,750	1,250	25,000
2-14	28,208	1,968	30,176	2,624	32,800
2-16	26,208	3,900	30,108	1,092	31,200
2-17	32,400	2,340	34,740	1,260	36,000
2-18	25,632	2,448	28,080	720	28,800
2-23	21,838	1,830	23,268	1,132	24,400
2-24	26,505	4,340	30,845	1,155	31,000
3- 5	25,536	7,560	33,096	504	33,600
3- 9	32,844	7,140	39,984	816	40,800
3-12	37,600	5,640	43,240	3,760	47,000
3-20	26,988	5,363	32,351	2,249	34,600
4- 5	43,050	2,706	45,756	3,444	49,200
4-12	34,176	2,688	36,864	1,536	38,400
4-18	26,195	4,185	30,380	620	31,000

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PAPERS ON PSYCHOLOGY AND EDUCATION

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THE PROBLEMS OF PERSONALITY

EDWARD S. ROBINSON, UNIVERSITY OF CHICAGO

It is my purpose in the present paper to examine the meaning of a topic in psychology which has lately been enjoying a rather remarkable popularity. I refer to what is being called "psychology of personality". While there are few books of the text or systematic sort which include a chapter on personality, there is still no doubt but that a definite chapter on this subject is being organized within the interests of that large group of thinkers engaged in the investigation of psychological and related problems. Certain sources, of course, lie more evidently at the basis of the development of this new chapter than do others. Those of you who have been in no more intimate contact with present-day psychology than through an occasional observation of book notices will recognize at once that this psychology of personality is somehow related to the activities of Freud and his school. Another outstanding, though less spectacular, source of our impetus toward personality study has grown out of the recent enthusiasm for psychological interpretations of social phenomena.

Sociologists and economists have found too wide a gap between the closely reasoned abstractions of conventional psychology and their own somewhat more concrete concerns. Their cries for a psychology of the synthesized and social individual have served as very potent stimuli for the study of personality.

It should be interesting to note just what sorts of facts the chapter on personality contains or is likely to contain. As I have already indicated, writers on personality are likely to keep the synthetic, integrated, psychophysical organism before them in a way which is not done by the general run of writers in psychology. This notion that the study of personality should especially emphasize those problems which arise only when the subject's activities are viewed in their integrated form

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is brought out very clearly by Watson[1] in his latest book. He tells us that we may think of the human being with all of his activities as analogous to a gas-engine with its carburetor, its pump, its magneto, and so on. While it may be highly desirable to understand the minutest aspects of human behavior, just as it is desirable to understand the details of the pump, carburetor, and magneto, it is also important to appreciate how the individual as a whole operates, just as it is important to appreciate how a gas-engine runs. There are unquestionably a number of psychologists who would object to making any distinction between a more analytic and a less analytic psychology. They would probably say that if one really analyzes mental activity thoroughly and accurately, one will *ipso facto* have a means of understanding, predicting, and controlling the activity of the individual as a whole. While I doubt whether any one would insist that analysis of mental life is at the present time complete enough for us to build up the semblance of a live individual out of reflexes, sensations, perceptions, and the like, it would probably be urged by the stauncher adherents of analysis that it is a sounder procedure to concern ourselves with the simple aspects of mental life until we have them well mastered, and then to proceed to the more complex. Logically, such a program has a certain appeal, but sciences in the direction of their growth, at least, are not necessarily logical. The demands of the clinician and the social scientist are likely to have far more influence upon the development of psychology than are the plans of the most logical program. I do not know just how fortunate or unfortunate is this fact. I put it forward simply as an argument for the belief that the psychologists of the near future are going to spend part of their time trying to observe and understand the organism as a whole.

Another characterization which might be made of the chapter on personality is that it is concerned more with the persistent trends or tendencies in behavior than it is with the structure of immediate experience. Instincts,

1. Psychology from the Standpoint of a Behaviorist, 1919, pp. 392 ff.

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as they are thought of by McDougall; sentiments, as they are thought of by Shand; complexes, as they are thought of by the psychoanalysts; and ambitions, ideals, hopes, and the like, as all of us understand them, would be of interest to the student of personality. The details of vision, of space perception, of memory, would not.

It is also fairly clear that the mental activities in which the student of personality is most interested are those which involve the social relationships of the individual. While all mental activities are necessarily social to some extent, the student of personality is usually interested in those activities which can be adequately described only by emphasizing the social character of the situation.

The desirability of getting the social view of the psychophysical organism is hardly open to debate. The proposition put forward at times, that this is really the only adequate view is, however, an over-statement of the case, to say the least. A social psychology undoubtedly gives better promise of applicability to the solution or interpretation of social problems, but we shall always have with us the seeing, hearing, feeling, remembering organism whose seeing, hearing, feeling, and remembering are being handled by a non-social psychology with an accuracy and adequacy which is to some degree a function of its lack of emphasis upon social issues.

When the psychologist comes across problems such as those of personality which require an unusual recognition of social factors, it would be well, it seems to me, if he kept in mind certain difficulties here in the way of keeping his thinking upon a scientific plane. Perhaps the greatest of these difficulties is the danger of mistaking ethical, social, and political issues for scientific or psychological issues. Social ethics, social hygiene, and political philosophy are of tremendous importance for human life, but the psychologist, even though his interest be primarily in serving them, must recognize that unless the standards of logic be dominant over all other standards his psychology will quickly become propaganda, and cease to function as science.

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There is still another even more subtle danger which must be guarded against where social factors are emphasized in the program of psychology. I refer to the danger of assuming, where there are fundamental distinctions from the standpoint of every-day life, that there must also be fundamental psychological distinctions. The mere fact that there are radicals and conservatives, religious and irreligious does not mean that these groups are necessarily important psychological types. It is true that we may describe the radical by means of a psychological terminology, but so may we describe icemen, and grocerymen, conductors, and policemen, and anybody and everybody in our world. If we did this, we should be merely counting the leaves on the trees.

In speaking of these things, I do not want to give the impression that I am minimizing the importance of recognizing the social factor in many psychological problems. I wish only to point out the difficulty in this case of keeping free, as scientists, from those standards and prejudices, many of them highly valuable in themselves, which permeate every social situation.

A fourth point which is likely to impress one is that the study of personality is concerned with facts that are somehow more intimate than those of the rest of psychology. The polarity between the individual and other things and other individuals comes in for a certain amount of stress. When it comes to this aspect of his problem, the student of personality finds that much of value has already been worked out by introspection. It seems to me that the dialectic of personal growth which has become an accepted part of our traditional psychology may with great profit be written as an important section into our contemporary treatment of personality.

I have been considering personality study in so far as it is concerned with general principles. There is also a differential psychology of personality which is receiving considerable attention. Ultimately, of course, the general and differential psychology of personality may be but different aspects of the same subject matter, but at present, this is hardly true. Those who have been

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interested in measuring individual differences in personal traits have, like the intelligence testers, worked on an almost purely empirical basis. The differential psychologist, in enumerating character traits, for instance, is bound to pick out the measurable rather than the fundamentally important.

A final question occurs to me in this attempt to interpret the appearance of a new chapter in psychology. Does this chapter contain, or is it likely to contain, any forms or principles of mental activity comparable in importance for psychology as a whole to the reaction arc, perception, image, idea, and habit? There are those who believe that the science of psychology will have largely to be rewritten as a result of modern studies of personality. Although time forbids an adequate defense of my position, I should like to say that I am extremely doubtful as to the truth of this statement. Most of the so-called new principles which have come into psychology with the recent studies in personality are after all not so very new. The notion of causal relationships between mental phenomena, the importance of unconscious activities, and the conception of conflict put forth so vividly by the psychoanalysts harken back to many historic systems and debates. I should not for a moment deny the paramount importance of the many neglected problems which recent studies of personality by the psychoanalysts and others have pointed out, but what is needed at the present time is not a proclamation that these mechanisms of personality are newly discovered phenomena, unrelated to any psychology heretofore thought of. Rather, there is a need, and I believe it is being increasingly acknowledged, for these personal mechanisms to be set in their proper relationships to that host of psychological principles which have been accumulating since Aristotle.

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THE VALIDITY OF ARITHMETICAL-REASONING TESTS

R. V. Hunkins and F. S. Breed, University of Chicago

The primary purpose of this investigation was to throw light on the relative validity of several arithmetical-reasoning tests now in use in the public schools. A secondary purpose was to explain in some measure the different degrees of merit shown by the different tests.

The following tests were used in the experiment:

(1) Daniel Starch: Arithmetical Scale A.

(2) C. W. Stone: Reasoning Test.

(3) W. S. Monroe: Standardized Reasoning Test in Arithmetic, Form 1.

(4) B. R. Buckingham: Scale for Problems in Arithmetic, Form 1.

(5) E. H. Chapple, S. A. Courtis, F. R. Matthews: Arithmetic Tests—Reasoning.

(6) R. M. Yerkes, M. E. Haggerty, L. M. Terman, E. L. Thorndike, G. M. Whipple: National Intelligence Tests, Scale A, Form 1, Test 1.

(7) M. E. Haggerty: Intelligence Examination, Delta 2, Exercise 2.

(8) A. S. Otis: Group Intelligence Scale, Advanced Examination, Form B, Test 5.

(9) L. M. Terman: Group Test of Mental Ability, Form A, Test 5.

(10) A. S. Otis: Group Intelligence Scale, Advanced Examination, Form B (complete).

For special reasons the results from tests (5) and (9) were not included for further study.

The subjects to whom the tests were administered were pupils in grades five to eight, inclusive, of a Hot Springs, S. D., public school. Complete data on all tests were secured from 127 subjects.

In advance of experimentation, a plan of administering the tests was devised to control such variables as time of day, day of week, and order of administration. All tests were administered and scored personally by Mr. Hunkins.

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Each reasoning test provided a single measure of the arithmetical-reasoning ability of each pupil. On the assumption that the average of several expert attempts to measure an object or reaction is more reliable than a single attempt, the average score of a pupil from several tests was regarded as approximating more closely the true measure of the ability in question than the measurement derived from a single test.

The average score was obtained after each test series had been transmuted into values on a percentile scale and thus made comparable. The method of transmutation was shown to have satisfactory reliability by the high correlation between each original series of scores and the corresponding derived series. The average coefficient (product-moment) was .99. The five tests which have but one set of problems for the four grades in which the experiment was conducted were employed in deriving the average or composite score.

The average coefficient of correlation of each test series with the composite in each grade was found, and the several tests ranked according to closeness of agreement with the composite.

For the purpose of verifying the results obtained by the use of the composite scores, all the possible inter-test correlation coefficients were computed for the sixth and seventh grades. The method of composite scores showed which test agreed most closely with the average result of five of the tests. The method of inter-test correlation showed which test on the average agreed most closely with the rest of the tests. The results by the two methods should be closely similar.

Table I presents the ranking of the tests according to the two different methods of estimating their validity.

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TABLE I

RANKING OF THE TESTS

Test	Method of Composite Scores	Method of Inter-test Correlation	Combined Ranks	Final Rank
National	5	4	9	4
Haggerty	2	3	5	2.5
Otis	3	2	5	2.5
Starch	4	6.5	10.5	5
Stone	1	1	2	1
Monroe	6	5	11	6
Buckingham	7	6.5	13.5	7

It should be remembered that in determining the composite score only five of the tests were used, Monroe and Buckingham being omitted. In determining the inter-test correlations, all the tests were used. It will be noted that the results by the two methods differ but slightly. It is important, however, to consider the inter-test values side by side with the other series, primarily because of the above omissions in the computation of the composite. Inclusion of a test in deriving the composite naturally tends to improve the rating of the test by the composite

The two series of ranks appearing in Table I were combined to form a final series representing the net result of the investigation. This final series is shown in the column designated "Final Rank." It will be observed that the Stone test occupies first position, the Haggerty and Otis tests divide honors for second place, the National ranks fourth, Starch fifth, Monroe sixth, and Buckingham seventh.

Analysis of the method and content of the tests revealed marked variations with respect to (1) length of time allowance, (2) selection of problems for different grades, (3) space for computation, (4) weighting of problems, (5) method of scoring, (6) use of preliminary exercises, (7) kind of problems. Most of these variables need further investigation in order to lay the foundation for more accurate tests of arithmetical-reasoning ability.

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THE INFUSION OF BAD BLOOD INTO A GOOD FAMILY

ELMER E. JONES, NORTHWESTERN UNIVERSITY

Few families have been so fortunate as to have escaped the infusion of bad blood into the line of descent. No matter how excellent the lineage from remote ancestors, there are to be found individuals in every family who have disregarded, either voluntarily or ignorantly, the family traditions, and have married into families whose blood is teeming with undesirable traits and characteristics. In some instances these traits have been so dominant as to overshadow practically all the good qualities of the family, and in the branch affected destroy its usefulness to society. The new science of Eugenics is bringing to light many instances in which a single unsocial dominant trait introduced into an otherwise excellent family has wrought its ruin. Whole branches of families have been wrecked by a single marriage starting a line of descent which is unsocial, mentally unbalanced or of low intelligence. Such tragedies are continually occurring, even among our most gifted and highly cultivated families.

This fact is frequently overlooked, viz., that there are many intelligent, and even gifted individuals who are members of degenerate families. Such individuals are very apt to migrate from the home community in which they were reared, in order to escape the stigma of the home to which they belong. They are intelligent enough to know that the "cards are stacked" against them so long as the world knows their ancestry. They migrate to remote regions in order to escape the disgrace. Here they may marry and propagate their kind unrestricted, provided, of course, the family tree remains unknown.

About fifteen years ago an intelligent boy belonging to a degenerate family in southern Indiana migrated to the State of Kansas, where he married a talented and well educated girl, the daughter of well-to-do parents of the middle class. The type of degeneracy well known in this man's family for several generations is a low grade

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of feeble-mindedness accompanied with viciousness and fits of anger followed by a prolonged state of coma. There are many criminals, police court cases, vandals, petty thieves, incendiaries, and delinquents. One branch of the family has been, at times, the occasion of much terrorism in northern Kentucky and several members of the family are now serving sentences in Indiana and Kentucky prisons.

As a result of this marriage five children were born, four of whom are perfectly normal, but one is typical of the degeneracy described above as characteristic of the father's family. At the present time he is eleven years of age, but has an intelligence quotent of 75, and is not capable of carrying the work of the second grade in school. He is a moral delinquent, already guilty of sexual perverseness and numerous petty thefts, is belligerent, high tempered and incorrigible. There is not the slightest doubt, even in the mind of his parents, that sooner or later he will become a ward of the State of Kansas. The family tree of this father, extending back only to his immediate parents, and including all his brothers and sisters with their children, is given below in Chart I.

The chart shows that this man's father was feeble-minded and his mother epileptic; that he had one normal brother and one normal sister; that he had two feeble-minded sisters who are not yet married, and one unmarried epileptic sister. It is little wonder that an intelligent man should wish to remove himself from such a home environment. The tragedy appears in his marriage into a good family, and his responsibility in bringing into the world offspring tainted with his own bad blood.

His feeble-minded son may never marry, and his other children may marry normal individuals whose children may all be normal; but the tragedy of a single life such as his son presents should be adequate warning against allowing such individuals to marry. Knowledge of his family tree would probably have deterred any intelli-

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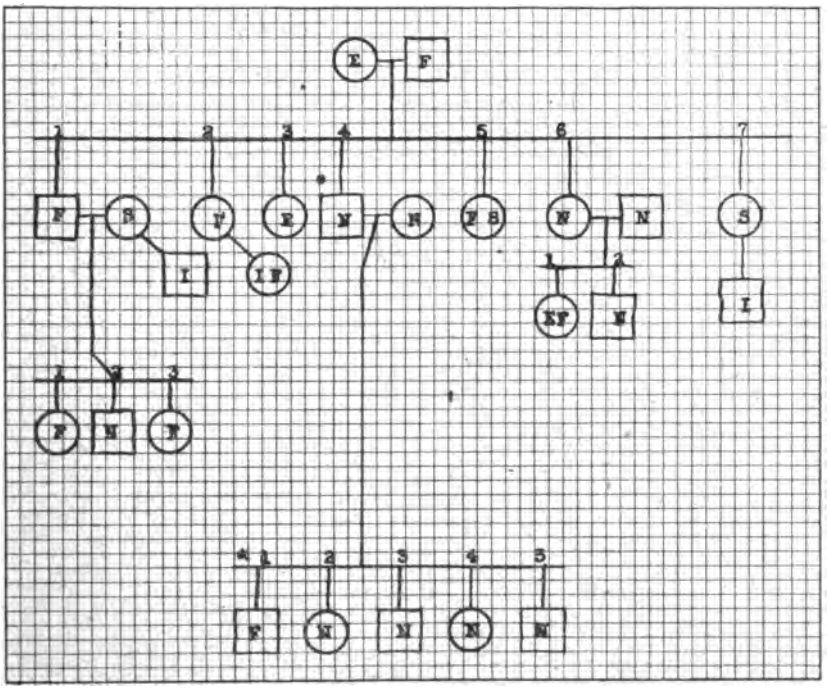

CHART I.

gent girl from considering with favor his suit for marriage.

Another case was recently brought to my attention by a social worker in the City of Chicago. Her charts showed that the girl under consideration belonged to a degenerate family which for almost a century has existed in southwestern Ohio. The girl herself is of normal intelligence, though of the servant girl class. She possessed enough energy and self reliance to break away from the home environment about fifteen years ago, and came to Chicago to live. Here she married a normal man of intelligence and excellent parentage, a mechanic of good ability.

This girl's family tree presents many cases of sexual perverseness, idiocy, imbecility, temporary insanity, feeble-mindedness, weakness, and almost always the most abject poverty. As a result of her marriage four children have been born, three of whom are perfectly

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normal, and one a low grade imbecile, incapable of training or education. Her family tree, extending back to her own parents and including her brothers and sisters, is given in Chart II.

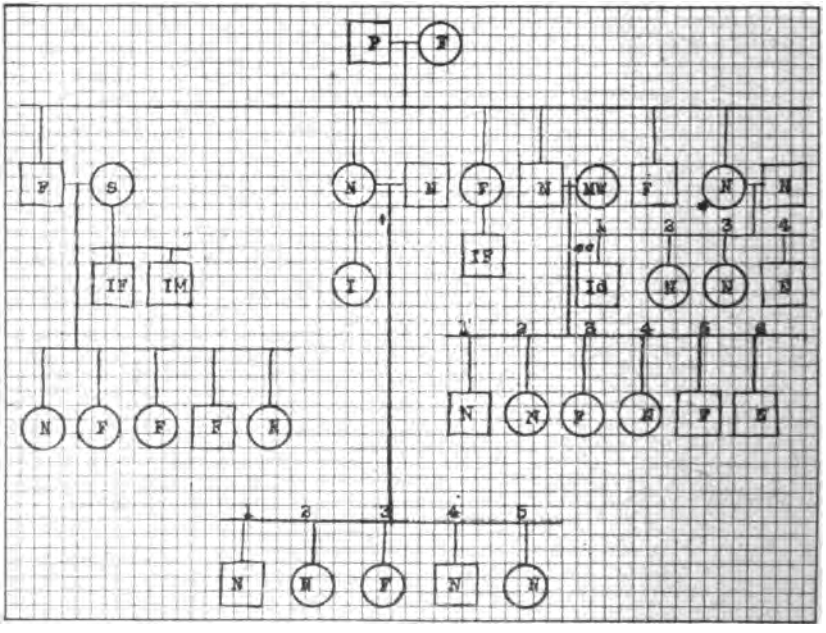

CHART II.

At present the writer is making a careful study of the descendants of a family which migrated from Pennsylvania to Eastern Indiana about 1820. They were Quakers, and believed in education, thrift, good citizenship, honesty, and peace. Approximately four hundred descendants have been traced, and the life and achievements of individuals carefully studied and tabulated. This family presents an enviable record of excellent citizenship, high ideals, and moral stamina. Throughout its long history the family has been represented in its descendants by men who have found simple duties in life and performed them with Christian fortitude. The ideals of service, so prominent in the Quaker religion, took deep root in the descendants of this family, and while few have gained distinction, nearly all belong to the great

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middle class of highly respected citizens of the commonwealth.

At least five of the descendants have been, or are at present, college professors, seventeen have served as high school principals or city superintendents; no less than thirty have taught in the elementary schools, and one is a Kindergartner of national reputation. Many have been and are at present successful farmers and stock raisers. One is president of a railroad corporation, another is president of a state labor organization, and there is one descendant who is probably a millionaire. There have been several Quaker preachers, and one Presbyterian preacher, though none of them have gained distinction in this field. In pre-Civil War days this family held very pronounced anti-slavery views, as did most Quakers, and maintained five well established stations of the "Underground Railroad" system reaching from Richmond, Indiana, to Fort Wayne. Hundreds of slaves made their escape to Canada over this route. The study reveals the fact that all the descendants have been law abiding, peace loving, gentle folk of good intelligence and decent behavior.

The marriages of the descendants, with one exception which will be discussed later, were uniformly favorable, producing offspring which conform more or less closely to the general type of native ability found throughout the family. The marriages were formerly held rather closely within the Quaker church, it being the custom of the sect not to marry outside. Since the Civil War, however, descendants have not at all conformed to this custom, whole branches of the family now being connected with other religious orders. All branches of the family have been practically free from mental and physical weakness, such as insanity, feeble-mindedness, cancer, and tuberculosis. Not a single instance of any of these maladies is recorded in the long history of this family. Infant mortality has been extremely low, which indicates a high degree of excellence in parental care.

In 1848 an event occurred in the history of this family tree which practically wrecked one branch of it. The

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eldest son of this original pair migrated to the state of Iowa and there married. His wife had been known to him only a short time, and it is probable that he did not know of the mental status of her forebears. At any rate this marriage initiated a series of tragedies scarcely surpassed in any Eugenics study with which I am familiar. The woman he married was attractive, intelligent, and a natural favorite. She lived to the age of sixty-six, a highly respected woman, a devoted mother, and died without showing any symptoms of the bad blood flowing in her veins.

All we know of this woman's family is that her father died in a hospital for the insane, she had one brother who committed a murder and then committed suicide rather than suffer arrest, another brother was guilty of sexual disorders, served a term in the penitentiary for rape, and finally committed suicide. Her mother died when the girl was thirteen years of age, and three children died in infancy, one supposedly in an epileptic fit. This record is sufficient to identify certain mental and moral traits which should not be transmitted.

The children of the original pair have all shown signs of the unsocial and diseased traits which were inherent in the family of the mother. The eldest daughter, a real Shakespearian shrew, while she was never actually insane, was always regarded as very peculiar. She talked almost continually during the waking period of her entire life. She was irritable, and unreasonable, an habitual scold, showed fits of passion at her children little short of real madness, was unclean in her person and house. Although she raised a large family of children, she never showed the slightest intelligence in the teaching of them, or the organization and administration of her home. She abused her husband and threatened to leave him many times. She talked about her own children in terms quite befitting them, for she apparently realized that her offspring were a degenerate lot. She gave birth to ten children, not one of whom ever gave her, or anyone else, any pleasure. Three girls were always called "half-witted" by relatives and friends. Two boys served jail sentences for serious sex crimes. Two others

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have served terms in the penitentiary for mail robbery and burglary. One daughter married a negro and has given birth to four children, three of whom are feeble-minded or worse. At least two of the daughters were common prostitutes. Little wonder that she railed at her family and blamed her husband for her troubles. It is quite clear, however, that the bad blood came from her own family, since her husband's family was free from any of the traits appearing in her offspring.

All the children in the family showed symptoms of degeneracy similar to that found in their grandmother's stock. Not one showed the virile traits of excellent capacity so prevalent in the father himself and his whole family. In this marriage all the factors of reproduction seemed to bring together and emphasize the unsocial qualities latent in the grandmother.

The diagram illustrates more fully the degeneracy of the whole group. The mother stated to the writer that her children among themselves committed practically every social irregularity known, including adultery, incest, pander, masturbation, theft, vulgarity, obscenity, etc. She talked about their unsocial disorders with great freedom, but with deep emotion.

The eldest son, No. 2 in Chart III, in the family for many years showed no signs of degeneracy. During his youth and adolescence he was self respectable, dignified, studious, and energetic. He was somewhat addicted to intoxicants, though not to excess. He married at twenty-four a woman of fine family, and considerable wealth. At about forty the degenerate traits of his mother's family began to show themselves. He was found guilty of sexual perverseness, was accused of financial irregularities in a county office, though not convicted because it was found that his guilt involved others of the county ring. Weaknesses of various kinds overtook him, including periodical melancholia, idleness, viciousness in his home and drunkness. At the age of fifty he had disgraced his wife and family in several debauches with disreputable people, and finally committed a sexual crime for which he was sentenced to prison for five years. A new trial brought in the insanity plea

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and he was sent to a sanatorium. The records of the institution show that he suffered a complete mental breakdown from which he never recovered. His case was diagnosed as "softening of the brain" from which he died after three years at the sanatorium.

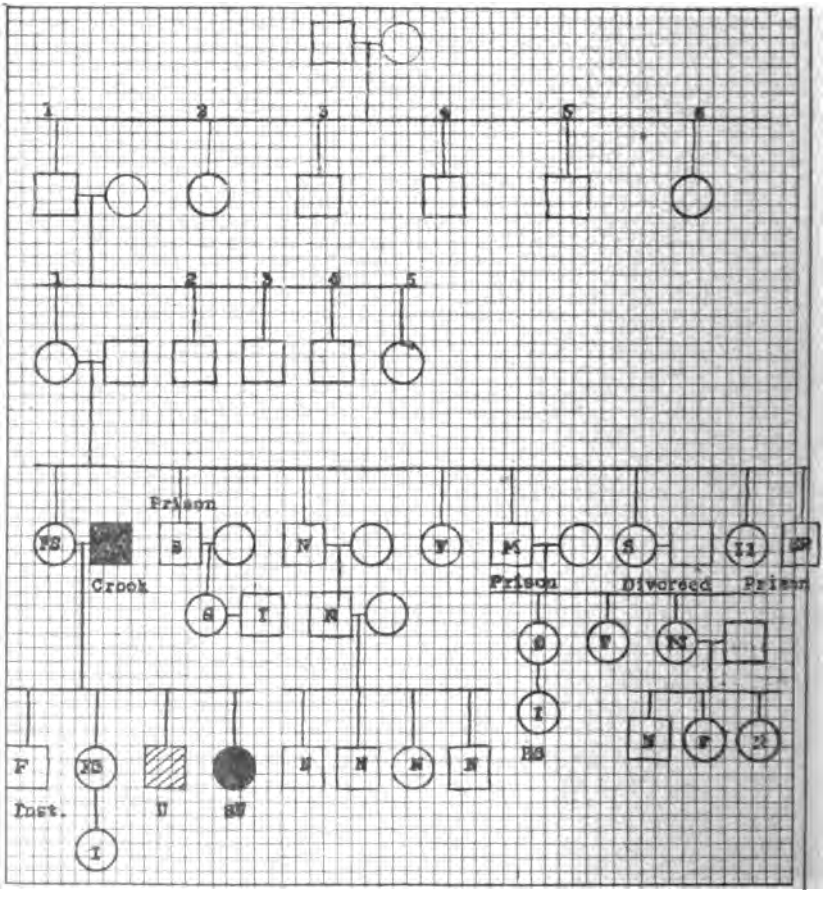

CHART III.

The second son, No. 3, Chart III, in the family showed no signs of degeneracy till he was somewhat over fifty years of age. During his youth he was a dudish chap, with little ambition except to dress gaudily and work as little as compatible with his dressing instinct. He was a cabinet maker of considerable proficiency and worked at

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this craft throughout his life. He never married, and became incompetent at fifty-four, when he was sent to a state sanitarium in a western state. His case was diagnosed as "softening of the brain" and he died at the age of sixty-one. His decline was quite similar to that of his brother, according to the copies of the records in my possession.

The third son, No. 4, Chart III, of this original pair seemed for many years to be normal in every respect. He was engaged in Government service with considerable distinction for a time, married well, and was the father of

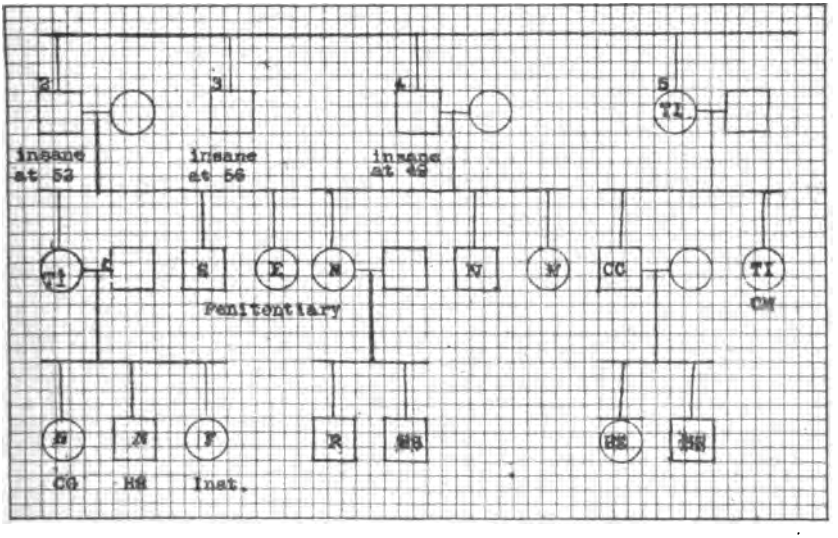

CHART IV.

three children. He provided a fine home in which was a considerable library, excellent pictures, and other means of culture usual in the best American families. He seemed to develop greatly after his school days, by much general reading and study, and was regarded most favorably by all who knew him. His social qualities were exceptional, and the best citizens in the community sought him out as a most companionable and versatile friend. Just when he had reached this point an event happened which shocked all who knew him but which was a harbinger of his future collapse. He was caught in fraudulent use of

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funds held in trust. The case was settled and a jail sentence suspended. He moved to another state and made a new start, but several minor lapses followed in quick succession. Once, an affair with a woman; another, a drunken spree for a few weeks in another city; and finally the selling of his property without the knowledge or consent of his wife. The money was quickly squandered, and his once happy home was wrecked. His downfall was rapid. The saloon, the brothel, the gambling den now became his haunts and he was rarely seen by his family. In a drunken row he was accused of killing his pal. By this time he had so far deteriorated from his former self that it was quite easy to prove him insane when he came up for trial. He was sent to the hospital for the insane in the state of Iowa, where he slowly deteriorated mentally and physically for about five years when he died.

His case turned out to be quite similar to that of his two elder brothers. The break came at about the same period of life or a little later, but the symptoms in the diagnoses were quite similar.

The youngest daughter, No. 5, Chart III, in this family is still living. She has never suffered a breakdown but has always been regarded as most peculiar. She married and is the mother of three children, but she has not lived with her husband for many years, nor do her children see her. She has long periods of depression during which she will not speak to her most intimate friends. These are probably forerunners of a final state of melancholia so common in her mother's family.

In the third generation the terrible effects of the unsocial dominant traits described in the parents are still evident. The accompanying charts show to what a low station many of the descendants of the original pair have sunk. One branch seems to have reached so low a stage that there is little danger of further propagation. From every standpoint the results have been disastrous. Economically it has been wasteful. Four states, Iowa, Missouri, Kansas and Nebraska, have expended approximately $18,000 in legal processes alone; a moderate esti-

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mate of hospital and asylum fees for the incompetents is placed at $20,000. The negative results entailed upon the community by mere residence of such socially unfit can never be estimated.

The question naturally arises, how long will society fail to comprehend this problem? How long will our marriage laws permit unsocial dominant traits to be freely propagated by any wretch who may possess them? It should be as difficult to get a marriage license as a life insurance policy. If men and women who contemplate marriage were compelled to submit with the application for the license a true family tree indicating family traits and hereditary tendencies, and if this application were compulsory long enough time before contemplated marriage to permit the state eugenist to pass upon the family of pedigrees, it is possible that two-thirds of the degenerate and unsocial qualities in the race could be eliminated.

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THE USE AND INTERPRETATION OF COEFFICIENTS OF CORRELATION

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Within the last few years the statistical device known as the coefficient of correlation has become extensively used in various phases of educational research. As a result, the interpretation of the coefficient of correlation has become a matter of major inportance. In the brief time that is allotted to me I desire to call attention to two conditions which affect the meaning to be attached to a given value of the coefficient of correlation.

In the first place, the magnitude of the coefficient of correlation is affected by a selection of the population from which it was calculated. When studying general relationships it is obvious that we must resort to sampling. For example, if we wish to ascertain the relation between success in Latin and success in English, it is necessary for us to answer this question on the basis of the relation that exists between these two achievements in a limited population. If two populations are selected in a random or unbiased manner the resulting coefficients will not be identical, except by chance. The differences, however, will not generally be large, and if we are justified in assuming that the selection is a random one, the fluctuations of the resulting coefficients of correlation conform to a general law. For any given value of the coefficient of correlation calculated from a known number of cases we can determine the probable error due to sampling by means of the formula

$$P.E._r = .6745 \frac{1 - r_{12}^2}{\sqrt{n}}$$

In certain types of educational research the magnitude of the coefficient of correlation is affected by other aspects of the selection of the population group from which it is calculated. In the case of certain traits, the range of the magnitude of the traits is a potent factor in determining the magnitude of the coefficient of correlation. For example, if we are studying the relation between in-

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telligence and achievement in silent reading, the coefficient of correlation will be much smaller when calculated from a random selection of the pupils belonging to a single half grade than when it is calculated from a random selection of pupils taken from grades three to eight, inclusive. In a recent study the coefficient of correlation between these two traits was calculated for each half grade from 3B to 8A, inclusive. The coefficients of correlation range from —.12 to .57. Since there were from 200 to 400 cases in each half grade the probable errors of these coefficients of correlation are relatively small. When the data from all grades were combined the coefficient of correlation for the same two traits was found to be .76. This is distinctly larger than the average of the coefficients of correlation for the separate half grades.

A more striking illustration is obtained from the correlation between chronological age and mental age. In the investigation referred to above, the coefficients of correlation were calculated between these two traits for each half grade. These range from —.12 up to —.44. In other words, the correlation between mental age and chronological age for the pupils belonging to a single half grade is inverse. In general, the pupils who are older chronologically tend to be the ones who are younger mentally, and vice versa. When the pupils from grades 3B to 8A, inclusive, are grouped together the correlation between chronological age and mental age was found to be .56. In this instance the coefficient is not only larger but it is positive, although when the pupils were taken by separate half grades all of the coefficients were negative. It, however, does not always happen that the coefficient of correlation is affected by the grade range from which the population is selected. For the same pupils the correlation was calculated between the intelligence quotient and the achievement quotient for arithmetic. When the pupils are taken by separate half grades, these coefficients range from —.19 to —.62. When all grades are taken together, the coefficient of correlation was found to be —.41, which is essentially the average of the coefficients of correlation for the separate half grades.

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It is, therefore, necessary to take into account the type of selection that is made as well as its random character. It is not enough to make the selection of data in an unbiased way. In addition, one must interpret the coefficient of correlation that is obtained with reference to the particular type of selection that has been followed. If all of the data have been obtained from the pupils belonging to a given half grade, the interpretation will be generally on a distinctly different basis from that to be followed if the data were selected in a random way from the pupils belonging to a sequence of several grades.

My second thesis is that the meaning to be attached to the numerical value of a coefficient of correlation depends upon the type of relationship being studied. For example, if we were studying the relation between general intelligence and quality of handwriting, a coefficient of correlation between these two traits of .40 would be high. If we were to obtain this result for a representative student population drawn from the sequence of several grades, we would be justified in asserting that for this group the relationship between general intelligence and quality of handwriting was very high. On the other hand, if we were studying the relation between first trial and second trial scores on an intelligence test we would consider a coefficient of .40 exceedingly low, if it was based upon a representative group of pupils from a sequence of several grades. In order for a coefficient of correlation to be considered high in this case it would need to be .80 or larger.

When these two illustrations are analyzed with reference to the questions we are attempting to answer by means of the coefficient of correlation, we find that we are dealing with questions which are not identical. In the case of the relationship between general intelligence and handwriting we are primarily concerned with ascertaining whether or not any relationship exists. If any does exist, it is very small. If we secure a positive coefficient of correlation which is three or four times larger than its probable error, we have evidence of a positive relationship between these two trials. We are, of course,

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interested somewhat in the closeness of this relationship, but since it is slight we have answered the question in so far as we are able when we have determined that a positive relationship does exist. On the other hand, when we are dealing with the relation between first trial scores and second trial scores on the same test we are not concerned with ascertaining whether a positive relationship exists between these sets of facts. We know from our general experience with educational tests that a relatively high positive relationship exists between first and second trial scores. The question which we wish to answer in this case is how nearly perfect is this relationship, or perhaps to put it into a more effective form, how great are the departures from a perfect relationship. If we compare the coefficient of correlation with its probable error due to sampling we obtain little or no assistance in interpreting it in such case. For example, we might have a coefficient of correlation of .65 with a probable error of ± .03. In this case the coefficient of correlation is more than 20 times its probable error, but the relationship between the first trial scores and the second trial scores is far from perfect.

In order to secure a measure of departure from a perfect correlation the probable error of estimate has been proposed for use instead of the coefficient of correlation. It may be calculated by means of the formula,

$$P.E._{Est} = .6745\ P\sqrt{1 - r_{12}}.$$

The calculation of the probable error of estimate, if the coefficient of correlation is known, involves some very simple arithmetic. It gives a measure of the magnitude of the departures from perfect correlation, or to put it in another way, it measures the amount of change which would be necessary in one set of data in order to bring them into perfect correlation with the other. For example, the correlation between the number of questions answered by eighty fourth grade children on forms 1 and 3 of the Courtis Silent Reading Test No. 2, was found to be .87 ± .02. In this case the coefficient of correlation is 43 times its probable error. This will be recognized as a very high correlation since it is based

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upon data of children from a single school grade. The probable error of estimate is 4.6. This means that in fifty percent of the cases one set of scores departed from perfect correlation with the other by more than 4.6 units. Since the average score is approximately 40 this amounts to about twelve per cent of the magnitude of the average scores.

In the formula for the probable error of estimate it will be noted that its magnitude depends upon the standard deviation of the distribution of the data from which the coefficient of correlation is computed as well as upon the coefficient of correlation. For this reason there is far from perfect correspondence between the magnitude of the probable error of estimate and the magnitude of the coefficient of correlation, even when the difference in the size of units is recognized by taking the ratio of the probable error of estimate to the average. For example, a certain collection of paired facts yielded a coefficient of correlation of .52. The probable error of estimate was 6.4 and the ratio of this to the average was .33. Another collection of data yielded a coefficient of correlation of .8, a probable error of estimate of 1.4 and the ratio of the probable error of estimate to the average of .14. A third collection of data yielded a coefficient of .51, a probable error of estimate of 17.6, and a ratio of .37. It will, therefore, be seen that widely different probable errors of estimate may be obtained for coefficients of correlation of approximately the same magnitude.

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THE INTELLIGENCE QUOTIENT—ITS ACCURACY AS A MEANS OF CLASSIFYING AND GRADING HIGH SCHOOL STUDENTS

W. P. MORGAN, PRESIDENT OF WESTERN ILLINOIS STATE TEACHERS COLLEGE

I. GENERAL STATEMENT OF CONDITIONS

The Western Illinois State Teachers College has a small High School or Academy as a practice school for students who are preparing to teach in high school.

In the fall of 1921, sixty-nine eighth grade graduates presented themselves for entrance to the ninth grade in this high school. Less than sixty could be accommodated. All were given scale B, form 1, of the National Intelligence Test. The following chart gives the I. Q.'s (intelligence quotients) of the fifteen students who applied for admission, but for reasons stated below the charts are not now in school.

In the charts and discussion in this paper each of the sixty-nine students is given an identification number in lieu of his real name.

A chart showing the I. Q.'s of the students who took the examination and did not complete the work of a quarter, with reasons.

Identification No.	I. Q.	Identification No.	I. Q.	Identification No.	I. Q.	Identification No.	I. Q.	Identification No.	I. Q.
3	94	18	85.1	30	76	41	126.5	55	77.5
4	84.7	22	76	31	100.7	43	103.2	56	101.3
8	67.4	23	131.3	33	93.5	46	86.9	57	82.5
10	85.5	25	86.9	35	109.3	47	73	62	112.3
13	66.6	27	85	36	102	52	76	67	107

8, 13, 30, and 55 were not admitted.
4, 10, 18, 25, 31, 41, 46, 52, 56, 57, and 67 did not appear for entrance.
23 died.
22 dropped out because of 23's illness.
3, 27, and 47 dropped out because of failure to do the work.
36 became ill.
33, 35, 43, and 62 dropped out without definite reason.

The fifty-four who entered were divided into two sections of twenty-seven each. The students with the higher I. Q.'s were put in section one while the students with the lower I. Q.'s were put in section two. At the present time twenty-five students from the original sec-

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tion one remain and nineteen students from section two are left.

These forty-four students have now been in school two quarters of twelve weeks each and have taken the same four subjects each quarter, except that during each quarter each section has had a few students who have taken biology instead of music or drawing, which the remainder of the sections took as their fourth subjects. Each student in the school is given a term credit for each subject which he takes each quarter. The passing grades beginning with the highest are A, A-, B, B-, and C, respectively. A grade of D is given for a term's work which is incomplete because of sickness or other valid excuse. E indicates failure.

The two charts which follow give each student in each section an identification number, state his I. Q. and show the grades he made in each subject each quarter.

A chart showing the I. Q.'s and Term Grades of Section One by subjects for the Fall and Winter Quarters.

		Fall Quarter				Winter Quarter			
Identification No.	I. Q.	Algebra	English	Geography	Drawing & Biology	Algebra	English	Geography	Music & Biology
1	109	B	B–	B	A	B–	B	B	B
2	102	C	C	C	A	E	B–	E	E
6	106	B–	B	B	B–	C	C	B	B
7	105	C	B	B	A–	C	B	A–	B
9	121	B	A–	B	A–	A–	B	B	A–
12	105.6	B	C	B	B	B–	C	B–	B
14	128	A	A–	A	A–	A	A–	A–	B
15	116	A–	A–	A	A	A	B	A	A–
19	119	B	C	B	A–	C	C	B–	B–
20	115	B–	B	A–	E	C	B	A–	E
21	141	A	A–	A	A–	A–	A	A	A–
26	103.2	B	B	B	B	B–	A–	B–	B
28	105	C	C	E	B	D	E	C	B–
29	116	B–	B–	C	B	B	B–	B	B
32	132	A	A–	A	A	A	A–	A–	A–
34	103	B	B	B	A–	B	A–	B	B
38	119	A	A–	A–	A–	A–	A–	D	B
44	109	B	B–	B	A–	C	B–	B	B
48	117.7	B–	C	C	B	B	C	B–	B
49	116.3	A–	B–	B	B	B	B	B	B
54	114	A–	B	B	A–	B	B	B	B
60	122	A–	B	A–	A	B	B	B	A–
63	129.8	A–	B	B	B	A–	B	A	B
64	121	B	B	A	A–	B–	A	A–	B
65	111.7	B	B–	B	B	B	B–	B	B

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A chart showing the I. Q.'s and Term Grades of Section Two by subjects for the Fall and Winter Quarters.

		Fall Quarter				Winter Quarter			
Identification No.	I. Q.	Algebra	English	Geography	Drawing & Biology	Algebra	English	Geography	Music & Biology
5	98	B–	C	C	B	C	C	C	B–
11	98	C	B–	B	A–	C	C	B–	C
16	93.2	B–	B–	C	B	B–	B–	B	B–
17	89.8	B	B–	B–	B–	B–	C	B–	B–
24	91.9	C	B	B	B	C	B–	B–	B
37	89	A–	B	A	B	A–	B–	A	A
39	100.9	B	B–	B	B–	B	B–	B	B–
40	87.6	C	B	B–	B	C	B–	C	B–
42	98.5	B–	B–	B–	C	C	C	C	B–
45	78	C	E	B	B	C	C	C	B
50	89	C	E	B	A–	E	C	B–	B
51	99	C	B–	C	A–	C	B–	B	B
53	101.4	A–	A	A	B	B	A–	A	A
58	91.2	A–	B	A	A–	A	B	A–	B
59	89	C	B	B	A–	C	B–	B–	E
61	97.1	E	B–	B–	B–	E	C	B	C
66	90	E	B–	B–	B–	E	C	B	C
68	88.4	C	B–	B–	B–	C	C	B–	B–
69	100.7	A	B	A	A–	A	B–	A	A–

The grades made by each section in each subject each quarter have been compiled so as to show the number of A grades made in Algebra in section one. Likewise the number of other grades in other subjects have been collected. The following chart shows the number of each of these grades as they have been collected.

A compilation of the various grades made in the four subjects in each section in the Fall and Winter Quarters.

FALL QUARTER

SECTION 1 (Class of 25)

Algebra	4 A's	5 A–'s	9 B's	4 B–'s	3 C's	
English	0 A's	6 A–'s	9 B's	5 B–'s	5 C's	
Geography	5 A's	3 A–'s	13 B's	0 B–'s	3 C's	1 E
Drawing and Biology	5 A's	10 A–'s	8 B's	1 B–	0 C's	1 E

SECTION 2 (Class of 19)

Algebra	1 A	3 A–'s	2 B's	3 B–'s	8 C's	2 E's
English	1 A	0 A–'s	5 B's	9 B–'s	2 C's	2 E's
Geography	4 A's	0 A–'s	6 B's	6 B–'s	3 C's	
Drawing and Biology	0 A's	6 A–'s	7 B's	5 B–'s	1 C	

WINTER QUARTER

SECTION 1

Algebra	3 A's	4 A–'s	7 B's	4 B–'s	5 C's	1 E	1 D
English	2 A's	5 A–'s	9 B's	4 B–'s	4 C's	1 E	
Geography	3 A's	5 A–'s	10 B's	4 B–'s	1 C	1 E	1 D
Drawing and Biology	1 A	4 A–'s	16 B's	2 B–'s	0 C's	2 E's	

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SECTION 2

Algebra	2 A's	1 A–	2 B's	2 B–'s	9 C's	3 E's
English	0 A's	1 A–	1 B	8 B–'s	9 C's	
Geography	3 A's	1 A–	5 B's	6 B–'s	4 C's	
Drawing and Biology	2 A's	1 A–	5 B's	7 B–'s	3 C's	1 E

II. RELATION OF GRADES MADE BY SECTIONS

By observing the above chart it is quite apparent that section one, which is the section with the higher I. Q.'s, has a much larger percentage of high grades and therefore a much smaller percentage of low grades than section two.

The same fact may be made much more striking by making a chart so that a graph showing the percentage of the various grades made by section one in Algebra in the Fall Quarter (or Term) may be set alongside a graph of the same thing for section two. In the following charts this has been arranged for all the subjects for each section for each Quarter.

If the charts for section one are compared with the charts for section two by subjects and the percentage of A's, A–'s, and B's is determined in each subject, it is observed that,—

1. In section one 72% of the Algebra grades, 70% of the English grades, 84% of the Geography grades, and 92% of the grades in Drawing and Biology fall in this group of grades in the Fall Quarter, while in section two 32% of the Algebra grades, 31% of the English grades, 53% of the Geography grades and 69% of the Drawing and Biology grades fall in this group.

2. In section one 56% of the Algebra grades, 66% of the English grades, 72% of the Geography grades and 84% of the grades in Music and Biology fall in this group of the grades in the Winter Quarter while in section two only 27% of the Algebra grades, 52% of the English grades, 47% of the Geography grades and 42% of the Music and Biology grades fall in this group.

3. Section one has most of its grades in all subjects congested with B's and A–'s in both terms, while section two has most of its grades congested with B–'s and C's.

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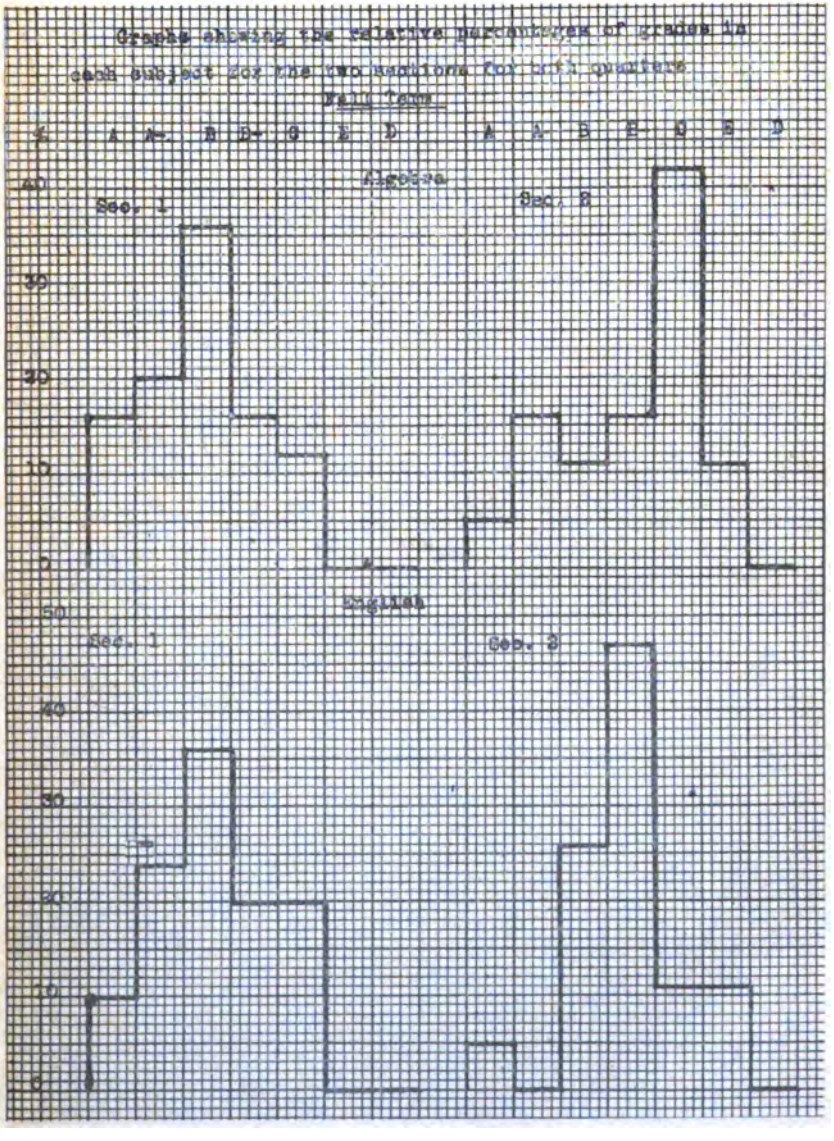

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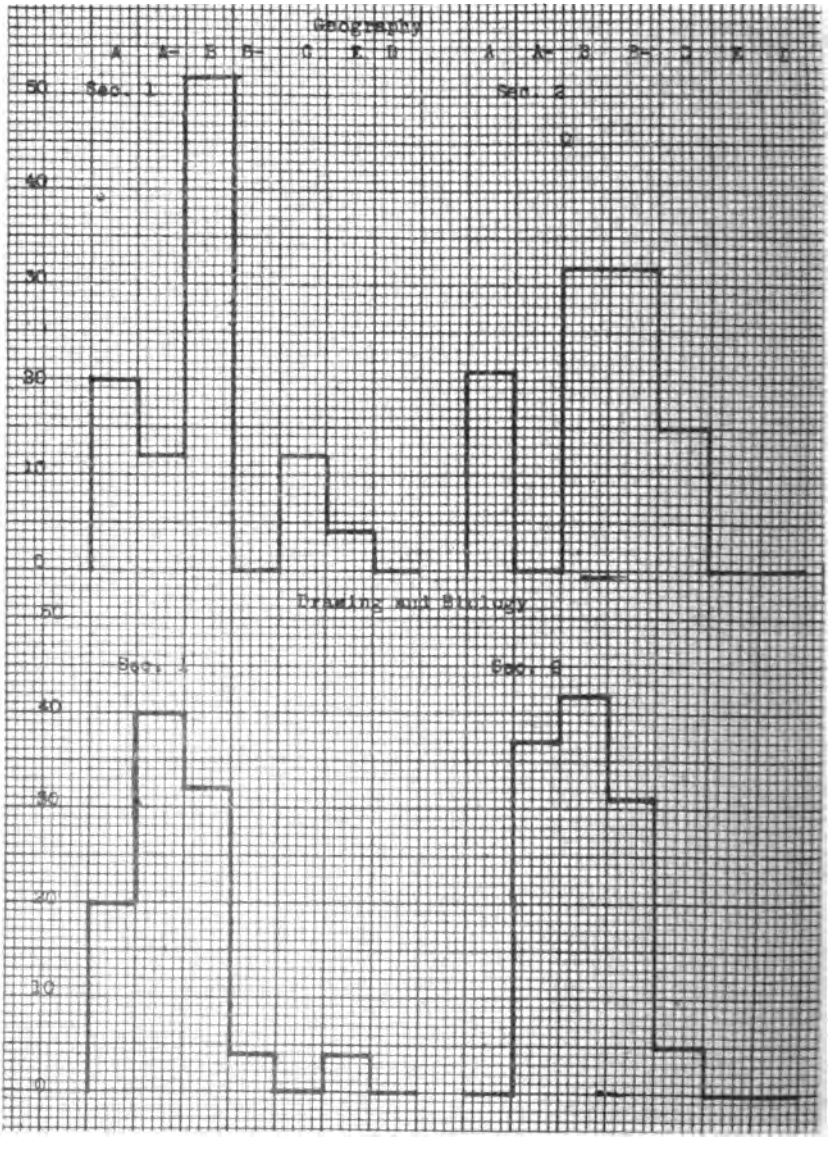

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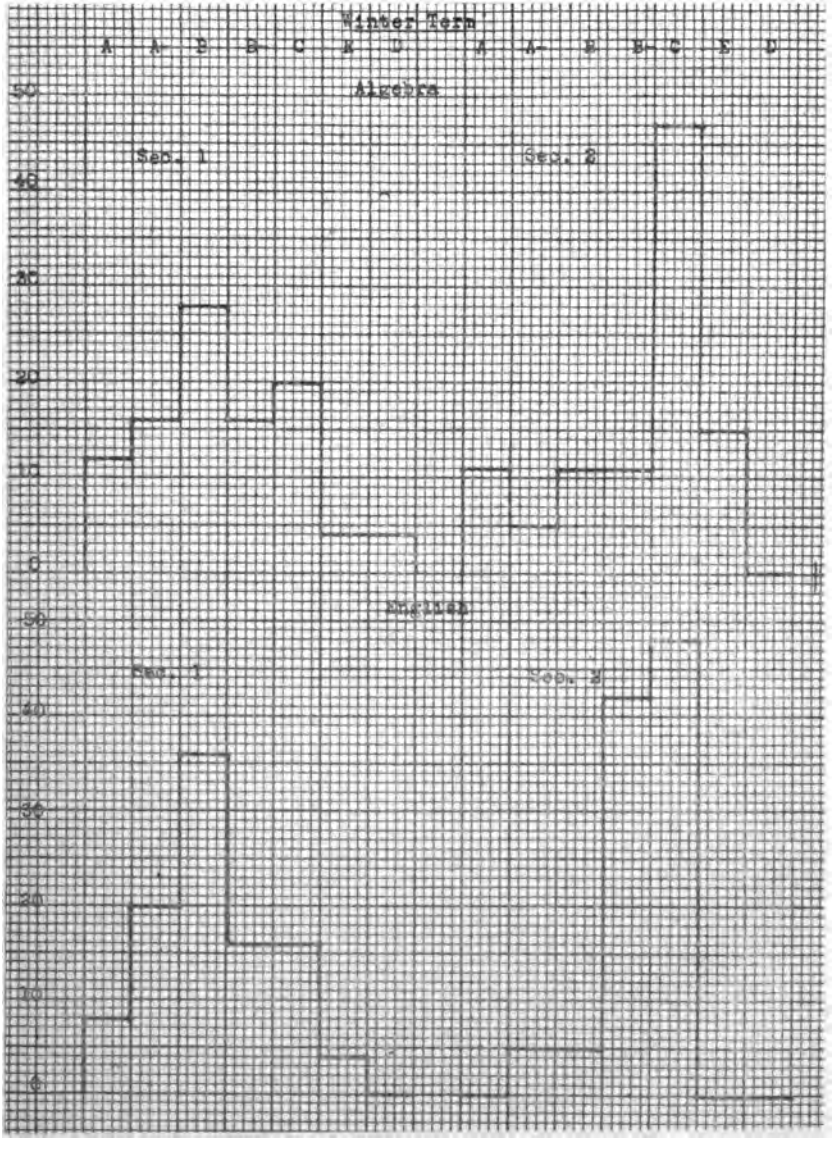

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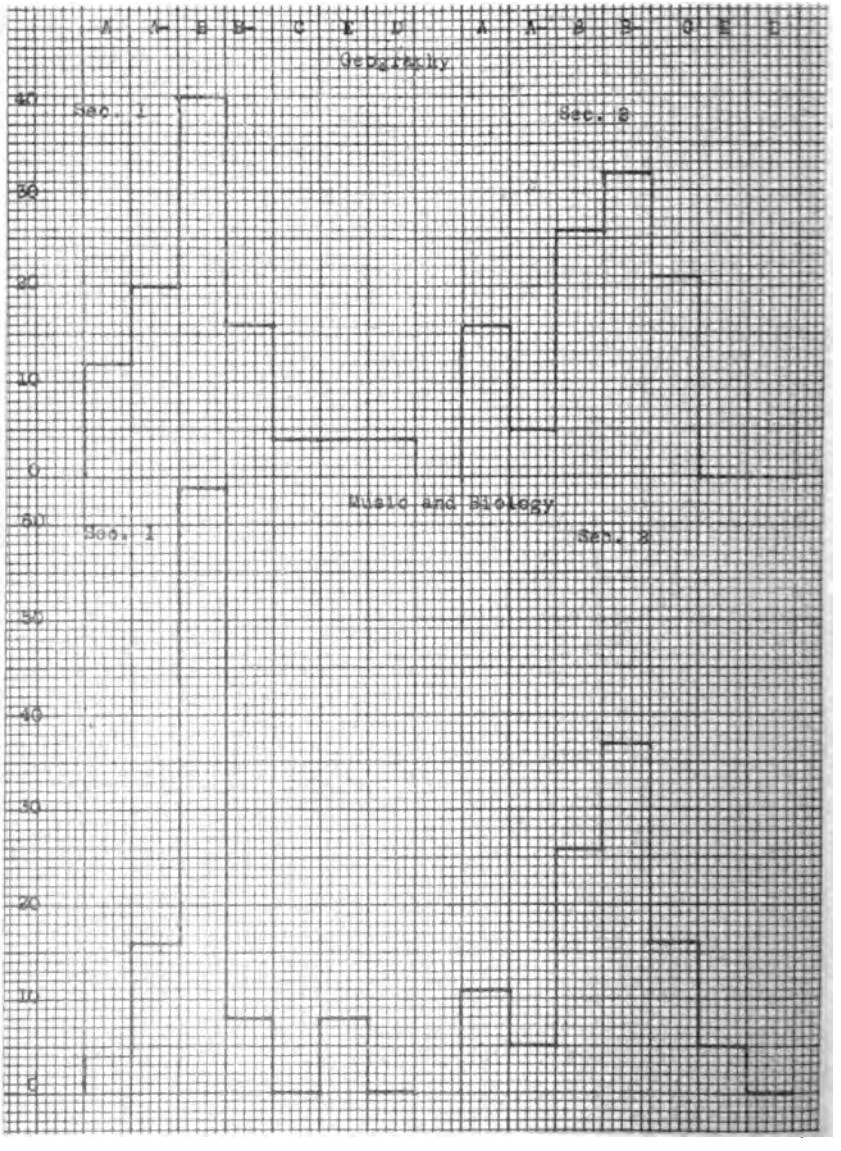

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4. Section one evidently is quite superior to section two.

III. CORRELATION OF I. Q.'S AND TERM GRADES

To determine the degree of correlation between the I. Q.'s and term grades of the pupils, each section is divided into quintiles on basis of the I. Q.'s of the students in it. These quintiles are marked 1, 2, 3, 4, and 5 beginning with the quintile composed of pupils with the higher I. Q.'s. Likewise the grades of the pupils in each section in each subject are divided into quintiles and are marked 1, 2, 3, 4, and 5 beginning with the quintile composed of the higher grades in each subject. The two charts which follow show the two sections with the identification number of each student in each section, the I. Q. of each student, the I. Q. quintile and each subject quintile in which the student's grades fall for both terms.

SECTION ONE

		Fall Quarter					Winter Quarter				
Identification No.	I. Q. Rank	Intell. Quintile	Algebra Quintile	English Quintile	Geog. Quintile	Draw. & Biol. Quintile	Intell. Quintile	Algebra Quintile	English Quintile	Geog. Quintile	Music & Biol. Quintile
1	18	4	3	4	4	1	4	4	4	4	4
2	25	5	5	5	5	1	5	5	4	5	5
6	19	4	4	3	4	5	4	4	5	4	4
7	22	5	5	3	5	3	5	5	3	2	4
9	7	2	2	2	2	2	2	2	2	2	1
12	20	4	3	5	4	4	4	4	5	4	4
14	4	1	1	1	1	1	1	1	1	1	4
15	13	3	2	1	1	1	3	1	3	1	1
19	8	2	3	5	2	2	2	4	5	5	5
20	14	3	4	3	2	5	3	5	3	2	5
21	1	1	1	1	1	2	1	1	1	1	1
26	23	5	4	3	4	4	5	4	2	5	3
28	21	5	5	5	5	5	5	5	5	5	5
29	12	4	5	4	5	4	4	3	4	4	3
32	2	1	1	1	1	1	1	1	1	1	1
34	24	5	4	3	4	3	5	3	2	4	3
38	9	2	1	1	2	2	2	2	1	2	2
44	17	4	3	4	3	3	4	5	4	3	3
48	10	2	5	5	5	3	2	2	5	5	2
49	11	3	2	4	3	4	3	3	3	3	2
54	15	3	2	2	3	3	3	2	3	3	3
60	5	1	1	2	2	1	1	2	2	3	1
63	3	1	2	2	3	5	1	1	2	1	2
64	6	2	3	2	1	2	2	3	1	2	2
65	16	4	4	4	3	5	4	3	4	3	5

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SECTION TWO

		Fall Quarter					Winter Quarter				
Identification No.	Intelligence Quotient Rank	Intelligence Quintile	Algebra Quintile	English Quintile	Geography Quintile	Drawing & Biol. Quintile	Intelligence Quintile	Algebra Quintile	English Quintile	Geography Quintile	Music & Biol. Quintile
5	7	2	2	5	5	2	2	2	3	4	3
11	6	2	4	2	2	2	2	3	3	3	4
16	9	3	2	3	5	3	3	2	3	2	3
17	13	4	2	4	4	4	4	2	4	4	4
24	10	3	4	2	3	3	3	3	3	3	2
37	16	4	1	2	1	3	4	1	2	1	1
39	2	1	2	3	2	4	1	1	1	2	3
40	18	5	3	2	4	3	5	4	2	5	4
42	5	2	3	4	3	5	2	3	4	5	3
45	19	5	5	5	3	4	5	4	5	5	2
50	15	4	3	5	2	2	4	5	4	4	2
51	4	1	3	4	5	1	1	3	1	2	1
53	1	1	1	1	1	2	1	2	1	1	1
58	11	3	1	1	1	1	3	1	1	1	2
59	14	4	4	1	2	1	4	4	2	3	5
61	8	2	5	3	3	4	2	5	4	2	5
66	12	3	5	3	4	5	3	5	5	3	5
68	17	5	4	4	4	5	5	4	5	4	4
69	3	1	1	1	1	1	1	1	2	1	1

By a study of the last two charts it is easy to determine whether a student whose I. Q. placed him in quintile 1, was also placed in quintile 1 by his Algebra grade. If so, there is a total correlation between his I. Q. and his Algebra grade. If by his I. Q. he is in quintile 2 but by his English grade he is in quintile 3, there is a variation of one quintile. It is readily observed, therefore, that there may be a total correlation, or a variation of one, two, three, or even four quintiles.

Checking through the two charts the following correlations and variations are discovered,—

Fall Term, Section One

ALGEBRA

1. Ten students had a total correlation of quintiles in their I. Q.'s and Algebra grades.

2. Fourteen students had a variation of but one quintile in their I. Q.'s and Algebra grades.

3. One student had a variation of three quintiles in his I. Q. and Algebra grade.

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ENGLISH

1. Twelve students had a total correlation.
2. Seven students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. Two students had a variation of three quintiles.

GEOGRAPHY

1. Fourteen students had a total correlation.
2. Eight students had a variation of one quintile.
3. Two students had a variation of two quintiles.
4. One student had a variation of three quintiles.

DRAWING AND BIOLOGY

1. Eleven students had a total correlation.
2. Seven students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. One student had a variation of three quintiles.
5. Two students had a variation of four quintiles.

Fall Term, Section Two

ALGEBRA

1. Five students had a total correlation.
2. Six students had a variation of one quintile.
3. Six students had a variation of two quintiles.
4. Two students had a variation of three quintiles.

ENGLISH

1. Seven students had a total correlation.
2. Four students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. Four students had a variation of three quintiles.

GEOGRAPHY

1. Five students had a total correlation.
2. Six students had a variation of one quintile.
3. Five students had a variation of two quintiles.
4. Two students had a variation of three quintiles.
5. One student had a variation of four quintiles.

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DRAWING AND BIOLOGY

1. Eight students had a total correlation.
2. Three students had a variation of one quintile.
3. Five students had a variation of two quintiles.
4. Three students had a variation of three quintiles.

Winter Term, Section One

ALGEBRA

1. Fourteen students had a total correlation.
2. Seven students had a variation of one quintile.
3. Four students had a variation of two quintiles.

ENGLISH

1. Thirteen students had a total correlation.
2. Seven students had a variation of one quintile.
3. One student had a variation of two quintiles.
4. Four students had a variation of three quintiles.

GEOGRAPHY

1. Sixteen students had a total correlation.
2. Four students had a variation of one quintile.
3. Two students had a variation of two quintiles.
4. Three students had a variation of three quintiles.

MUSIC AND BIOLOGY

1. Twelve students had a total correlation.
2. Seven students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. Two students had a variation of three quintiles.

Winter Term, Section Two

ALGEBRA

1. Five students had a total correlation.
2. Eight students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. Two students had a variation of three quintiles.

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ENGLISH

1. Nine students had a total correlation.
2. Three students had a variation of one quintile.
3. Six students had a variation of two quintiles.
4. One student had a variation of three quintiles.

GEOGRAPHY

1. Nine students had a total correlation.
2. Six students had a variation of one quintile.
3. Two students had a variation of two quintiles.
4. Two students had a variation of three quintiles.

MUSIC AND BIOLOGY

1. Five students had a total correlation.
2. Seven students had a variation of one quintile.
3. Four students had a variation of two quintiles.
4. Three students had a variation of three quintiles.

If we consider total correlation as 100% correlation; variation of one quintile as 75% correlation; variation of two quintiles as 50% correlation; variation of three quintiles as 25% correlation; and variation of four quintiles as 0% correlation, the following statements are true,—

1. In the Fall Quarter section one had 84% correlation in Algebra; 79% correlation in English; 85% correlation in Geography; and 74% correlation in Drawing and Biology.

2. In the Fall Quarter section two had 68.4% correlation in Algebra; 68.4% correlation in English; 65.8% correlation in Geography; and 71% correlation in Drawing and Biology.

3. In the Winter Quarter section one had 85% correlation in Algebra; 79% correlation in English; 83% correlation in Geography; and 79% correlation in Music and Biology.

4. In the Winter Quarter section two had 71% correlation in Algebra; 76.3% correlation in English; 79% correlation in Geography; and 68.4% correlation in Music and Biology.

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5. In all subjects in the Fall Quarter section one had 80.5% of correlation and section two had 68.4% of correlation.

6. In all subjects in the Winter Quarter section one had 81.5% of correlation and section two had 73.7% of correlation.

7. In all subjects in both quarters both sections had 76.7% of correlation.

From the above it seems probable that the I. Q.'s of students will give a teacher rather reliable evidence as to what may be expected of these students in high school subjects in the ninth grade.

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CONSTITUTION AND BY-LAWS

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CONSTITUTION AND BY-LAWS

Illinois State Academy of Science

CONSTITUTION

Article I. Name.

This Society shall be known as The Illinois State Academy of Science.

Article II. Objects.

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

Article III. Members.

The membership of the Academy shall consist of two classes as follows: *National Members* and *Local Members*.

National Members shall be those who are also members of the American Association for the Advancement of Science. Each national member, except life members of the Academy, shall pay an admission fee of one dollar and an annual assessment of five dollars.

Local Members shall be those who are members of the local Academy only. Each local member, except life members of the Academy, shall pay an admission fee of one dollar and an annual assessment of one dollar.

Both national members and local members may be either *Life Members*, *Active Members*, or *Non-resident Members*.

Life Members shall be national or local members who have paid fees to the Academy to the amount of twenty dollars. Life members, if national members, shall pay an annual assessment of four dollars.

Active Members shall be national or local members who reside in the State of Illinois, and who have not paid as much as $20.00 in fees to the Academy.

Non-resident Members shall be active members or life members who have removed from the State of Illinois. Their duties and privileges shall be the same as active members except that they may not hold office.

Charter Members are those who attended the organization meeting in 1908, signed the constitution, and paid dues for that year.

For election to any class of membership, the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

Article IV. Officers.

The officers of the Academy shall consist of a President, a Vice-President, a Librarian, a Secretary, and a Treasurer. The chief of the Division of State Museum of the Department of Registration and Education of the state government shall be the Librarian of the Academy. All other officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

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It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Librarian shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council.

The Council shall consist of the President, Vice-President, Secretary, Treasurer, Librarian, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees.

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership and such other committees as the Academy shall from time to time deem desirable.

The Committee on Publication shall consist of the President, the Librarian, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings.

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council, and shall be called upon written request of twenty members.

Article VIII. Publications.

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation.

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and may be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments.

This constitution may be amended by a three-fourths vote of the membership present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

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II. No meeting of the Academy shall be held without thirty days previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Librarian shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary. No paper shall be presented at any meeting, by any person other than the author, except on vote of the members present at such meeting.

IX. The Secretary and Treasurer shall have their expenses paid from the Treasury of the Academy while attending council meetings and annual meetings. Other members of the council may have their expenses paid while attending meetings of the council, other than those in connection with annual meetings.

X. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

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LIST OF MEMBERS

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List of Members

Note—The names of charter members are starred; names in black faced type indicate membership in the American Association for the Advancement of Science.

LIFE MEMBERS.

***Andrews, C. W.**, LL. D., The John Crerar Library, Chicago (Sci. Bibl.).
*Bain, Walter G., M. D., St. John's Hospital, Springfield (Bacteriology).
Barber, F. D., M. S., Illinois State Normal University, Normal (Physics).
Barnes, R. M., LL. B., Lacon (Zoology).
Barnes, William, M. D., Decatur (Lepidoptera).
***Bartow, Edward**, Ph. D., University of Iowa, Iowa City.
Chamberlain, C. J., Ph. D., University of Chicago, Chicago (Botany).
Chamberlin, T. C., LL. D., University of Chicago, Chicago (Geology).
Cowles, H. C., Ph. D., University of Chicago, Chicago (Botany).
***Crew, Henry**, Ph. D., Northwestern University, Evanston (Physics).
***Crook, A. R.**, Ph. D., Chief, Museum, Springfield (Geology).
Deal, Don W., M. D., Leland Office Building, Springfield (Medicine).
Farrington, O. C., Ph. D., Field Museum, Chicago (Minerology).
Ferriss, J. H., Joliet (Conchology).
***Fischer, C. E. M., M. D.**, Marshall Field Annex Bldg., Chicago (Biology).
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Fuller, Geo. D., Ph. D., University of Chicago, Chicago (Botany).
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***Hessler, J. C.**, Ph. D., James Millikin University, Decatur (Chemistry).
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***Smith, Isabel Seymour**, M. S., Illinois College, Jacksonville (Botany).
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Washburn, E. W., Ph. D., University of Illinois, Urbana (Chemistry).
Weller, Annie L., Eastern Illinois State Normal School, Charleston.
***Weller, Stuart**, Ph. D., University of Chicago, Chicago (Paleontology).
Zeleny, Charles, Ph. D., University of Illinois, Urbana (Experimental Zoology).

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